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Aggregate Resources Inventory of the
Hemlo Area
Districts of Thunder Bay and Algoma

By Staff of the Engineering and Terrain Geology Section, Ontario Geological Survey

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Aggregate Resources Inventory of the Hemlo Area
Districts of Thunder Bay and Algoma

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by
Staff[1] of the Engineering and Terrain Geology Section

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Abstract

This report includes an inventory and evaluation of sand and gravel resources as well as a discussion of bedrock aggregate potential in the Hemlo Area in north-central Ontario. It is based on a detailed field assessment undertaken in the autumn of 1983 and spring of 1984 along with Quaternary geology mapping in the White Lake and Cedar Lake map areas by R.S. Geddes and A.F. Bajc (1985a; 1985b) of the Engineering and Terrain Geology Section, Ontario Ontario Geological Survey, and in the municipalities of Marathon, Manitouwadge and White River by F.J. Kristjansson of the North Central Region, Ontario Ministry of Natural Resources. Quaternary geology mapping in the municipalities was funded by the Ontario Ministry of Northern Affairs.

In the project area, twenty-three areas containing significant amounts of sand and gravel have been selected for possible resource protection at the primary level of significance. Selected Sand and Gravel Resource Areas occupy 9800 acres (3950 ha). An estimated 8500 acres (3450 ha) are currently available for extraction, containing resources of approximately 670 million tons (610 million tonnes). In addition, numerous deposits have been classified as resources of secondary significance which add considerably to the resource base of the report area.

Included within the study area is the site of the most important recent gold discovery in Canada. The discovery of large gold deposits near Hemlo in 1981 has initiated the development of three mines. Construction of these mines and associated mills has already placed a great demand on local aggregate resources and this demand is expected to increase as development continues. Within a 20-kilometre radius of the Hemlo mining camp, six areas have been selected at the primary level of significance and several deposits have been classified as secondary resources. These sand and gravel deposits, together with a bedrock quarry established near the mine sites, should be capable of meeting most mine construction requirements.

As a result of the mine developments at Hemlo, the municipalities in the area expect their populations to increase. Consequently, a higher municipal demand for aggregate is expected. Within the municipalities of Marathon, Manitouwadge and White River, eight areas have been selected at the primary level of significance. These resource areas, along with several secondary selected deposits, appear adequate to meet most municipal demands.

Within the report area many deposits have been selected in remote areas or in areas where present aggregate demand is considered low. Nevertheless, these deposits are considered to be valuable future sources of aggregate, which may increase in importance if activities such as road construction are undertaken in their vicinity, or if future mines are developed in those areas.

The project area is underlain predominantly by granitic, metasedimentary and metavolcanic rocks of the Precambrian Shield. Of these, the granitic rock is considered best suited as a potential aggregate source. One granodiorite quarry has recently been established near the Hemlo camp to supply crushed aggregate products.

Selected Resource Areas are not intended to be permanent, single land use units. They represent areas in which a major resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection.

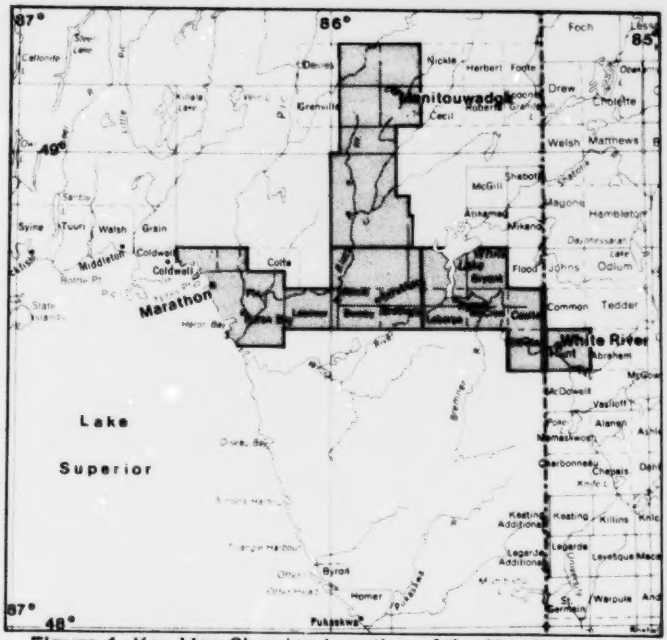


Figure 1. Key Map Showing Location of the Hemlo Area.
Scale 1:1 584 000.

Introduction

Mineral aggregates, which include bedrock-derived crushed stone as well as naturally formed sand and gravel, constitute the major raw material in Ontario's road-building and construction industries. Very large amounts of these materials are used each year throughout the Province. For example, in 1982, the total tonnage of mineral aggregates extracted was 101 million tons (92 million tonnes), greater than that of any other metallic or nonmetallic commodity mined in the Province (Ontario Ministry of Natural Resources 1983).

Although mineral aggregate deposits are plentiful in Ontario, they are fixed-location, nonrenewable resources which can be exploited only in those areas where they occur. Mineral aggregates are characterized by their high bulk and low unit value so that the economic value of a deposit is a function of its proximity to a market area as well as its quality and size. The potential for extractive development is usually greatest in areas where land use competition is extreme. For these reasons the availability of adequate resources for future development is now being threatened in some areas.

Comprehensive planning and resource management strategies are required to make the best use of available resources, especially in those areas experiencing rapid development. Such strategies must be based on a sound knowledge of the total mineral aggregate resource base at both local and regional levels. The purpose of the Aggregate Resources Inventory is to provide the basic geological information required to include potential mineral aggregate resource areas in planning strategies. The reports should form the basis for discussion on those areas best suited for possible extraction. The aim is to assist decision-makers in protecting the public well-being by ensuring that adequate resources of mineral aggregate remain available for future use.

This report is a technical background document, based for the most part on geological information and interpretation. It has been designed as a component of the total planning process and should be used in conjunction with other planning considerations, to ensure the best use of the resources.

The report includes an assessment of sand and gravel resources as well as a discussion on the potential for bedrock- derived aggregate. The most recent information available has been used to prepare the report. As new information becomes available, revisions may be necessary.

Part I — Inventory Methods

FIELD AND OFFICE METHODS

The methods used to prepare the report primarily involve the interpretation of published geological data such as bedrock and surficial geology maps and reports (see References) as well as field examination of potential resource areas. Field methods include the examination of natural and man-made exposures of granular material. Most observations are made at quarries and sand and gravel pits located from records held by the Ontario Ministry of Transportation and Communications, the Ontario Geological Survey, and by Regional and District Offices of the Ontario Ministry of Natural Resources. Observations made at pit sites include estimates of the total face height and the proportion of gravel- and sand-sized fragments in the deposit. Observations also are made of the shape and lithology of the particles. These characteristics are important in estimating the quality and quantity of the aggregate. Test pitting, soil probing, hand-augering and geophysical techniques are used to assess subsurface materials in areas of limited exposure. Airphotos at various scales are used to determine the continuity of deposits, especially in areas where information is limited.

Deposits with potential for further extractive development or those where existing data are scarce, are studied in greater detail. Representative sections in these deposits are sampled in 25- to 100-pound (11 to 45 kg) units from existing pit faces or from test pits. The samples are analysed for grain size distribution, and in some cases Los Angeles abrasion, absorption and Magnesium Sulphate soundness tests along with petrographic analyses are performed. Analyses are performed either in the laboratories of the Soils and Aggregates Section, Engineering Materials Office, Ontario Ministry of Transportation and Communications or in the Geoscience Laboratories, Geoservices Section, Ontario Geological Survey. Test holes excavated by a wheeled backhoe and geophysical surveys using hammer seismic equipment provide data in areas of limited subsurface exposure. The symbols for and locations of sample and test hole sites along with geophysical traverse lines are noted on Maps 1A, 1B and 1C. The sediments revealed in the test holes and the geophysical data are summarized in Tables 4 and 5, respectively.

In the office, the field data are supplemented by pit information on file with the Soils and Aggregates Section of the Ontario Ministry of Transportation and Communications. Data contained in these files include field estimates of the depth, composition and "workability" of deposits as well as laboratory analyses of the physical properties and chemical suitability of the aggregate. Information concerning the development history of the pits and acceptable uses of the aggregate is also recorded. The locations of additional sources are obtained from records held by Regional and District Offices of the Ontario Ministry of Natural Resources. The cooperation of the above-named groups in the compilation of inventory data is gratefully acknowledged.

Water well records, held by the Ontario Ministry of the Environment, are used in some areas to corroborate thickness estimates or to indicate the presence of buried granular material. These records are used in conjunction with other evidence. Topographic maps of the National Topographic System, at a scale of 1:50 000, are used as a compilation base for the field and office data. The information is then transferred to a base map, also at a scale of 1:50 000, prepared by the Cartography Section of the Lands and Waters Group, Ontario Ministry of Natural Resources, for presentation in the report.

RESOURCE TONNAGE CALCULATION TECHNIQUES

SAND AND GRAVEL RESOURCES

Once the interpretative boundaries of the aggregate units have been drawn, quantitative estimates of the possible resources available can be made. Generally, the volume of a deposit can be calculated if its areal extent and average thickness are known or can be estimated. The computation methods used are as follows. First, the area of the deposit, as outlined on the final base map, is calculated in acres. The thickness values used are an approximation of the deposit thickness, based on the face heights of pits developed in the deposit or on subsurface data such as test holes and water well logs. Original tonnage values can then be calculated by multiplying the volume of the deposit by 2500 (the density factor). This factor is approximately the number of tons in a one-foot (0.3 m) thick layer of sand and gravel, one acre (0.4 ha) in extent, assuming an average density of 110 pounds per cubic foot (1766 kg per cubic metre).

Tonnage = Area x Thickness x Density Factor

Tonnage calculated in this manner must be considered only as an estimate. Furthermore, such tonnages represent amounts that existed prior to any extraction of material (i.e. original tonnage) (Table 1, Column 4).

The Selected Sand and Gravel Resource Areas in Table 3 are calculated in the following way. Two successive subtractions are made from the total area. Column 3 accounts for the number of acres unavailable because of the presence of permanent cultural features and their associated setback requirements. Column 4 accounts for those areas that have previously been extracted. The remaining figure is the area of the deposit currently available for extraction (Column 5). The available area is then multiplied by the estimated deposit thickness and the density factor (Column 5 x Column 6 x 2500) to give an estimate of the sand and gravel tonnage (Column 7) presently available for extractive development and/or resource protection.

Reserve estimates are calculated for deposits of primary significance. Reserve estimates for deposits of secondary and tertiary significance are not calculated in Table 3, however the aggregate potential of these deposits is discussed in the report.

UNITS AND DEFINITIONS

Although most of the measurements and other primary data available for resource tonnage calculations are given in Imperial units, Metric units have also been given in the text and on the tables which accompany the report. The Metric equivalent of the data is shown in brackets after or directly below the corresponding Imperial figures. Data are generally rounded off in accordance with the Ontario Metric Practice Guide (Metric Committee 1975).

The tonnage estimates made for sand and gravel deposits are termed possible resources in accordance with terminology of the Ontario Resource Classification Scheme (Robertson 1975, p.7) and with the Association of Professional Engineers of Ontario (1976) (see Glossary, Appendix B).

Part II — Data Presentation and Interpretation

For each map area there are two maps, each portraying a different aspect of the aggregate resources in the report area. Maps 1A, 1B and 1C, "Distribution of Sand and Gravel Deposits", give a comprehensive inventory of the sand and gravel resources in the report area. Maps 2A, 2B and 2C, "Selected Sand and Gravel Resource Areas", show those deposits which are considered to represent the largest and/or highest quality resources in the area.

MAPS 1A 1B and 1C: DISTRIBUTION OF SAND AND GRAVEL DEPOSITS

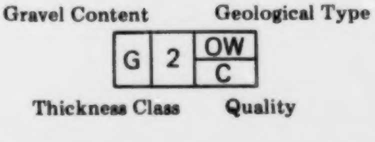
Maps 1A, 1B and 1C are derived from existing surficial geology maps of the area or from airphoto interpretation in areas where surficial mapping is incomplete. The maps show the extent and quality of sand and gravel deposits within the study area and the present level of extractive activity.

On the maps, gravel deposits are indicated by dark brown shading while sand deposits are shaded light brown. Pits are shown by a solid dot and identified by a number which refers to the pit descriptions in Table 2. Each description notes the location of the pit, as well as the estimated face height and percentage gravel.

Maps 1A, 1B and 1C also present a summary of available information related to the quality of aggregate contained in all the known aggregate deposits in the study area. Much of this information is contained in the symbols which are found on the maps. The Deposit Symbol appears for each mapped deposit and summarizes important genetic and textural data. The Texture Symbol is a circular proportional diagram which displays the grain size distribution of the aggregate in areas where bulk samples were taken.

DEPOSIT SYMBOL

The Deposit Symbol is similar to those used in soil mapping and land classification systems commonly in use in North America. The components of the symbol indicate the gravel content, thickness of material, origin (type), and quality limitations for every deposit shown on Maps 1A, 1B and 1C. These components are illustrated by the following example:



This symbol identifies an outwash deposit 10 to 20 feet (3 to 6 m) thick containing more than 35 percent gravel. Excess silt and clay may limit uses of the aggregate in the deposit.

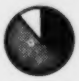
The "gravel content" and "thickness class" are basic criteria for distinguishing different deposits. The "gravel content" symbol is an upper case "S" or "G". The "S" indicates that the deposit is generally "sandy" and that gravel-sized aggregate (greater than 4.75 mm) makes up less than 35 percent of the whole deposit. "G" indicates that the deposit contains more than 35 percent gravel.

The "thickness class" indicates a depth range which is related to the potential resource tonnage for each deposit. Four thickness class divisions have been established as shown in the legend for Maps 1A, 1B and 1C.

Two smaller sets of letters, divided from each other by a horizontal line, follow the thickness class number. The upper series of letters identifies the geologic deposit type (the types are summarized with respect to their main geologic and extractive characteristics in Appendix C) and the lower series of letters identifies the main quality limitations that may be present in the deposit as discussed in the next section.

TEXTURE SYMBOL

The Texture Symbol provides a more detailed assessment of the grain size distribution in deposits where samples were taken for analysis during field study. The information from which these symbols are derived has been plotted in grain size distribution graphs. The relative amounts of gravel, sand, and silt and clay in the sampled material are shown graphically by the subdivision of a circle into proportional segments. The following example shows a hypothetical sample consisting of 30 percent gravel, 60 percent sand, and 10 percent silt and clay:



Test hole locations are shown on Maps 1A, 1B and 1C by a solid drill hole symbol. Geophysics lines are shown on the maps by a line symbol.

MAPS 2A, 2B and 2C: SELECTED SAND AND GRAVEL RESOURCE AREAS

Maps 2A, 2B and 2C are interpretative maps derived from an evaluation of the deposits shown on Maps 1A, 1B and 1C. The deposits identified on Maps 2A, 2B and 2C are those which are considered to be important in ensuring an adequate resource base for the future.

All the selected sand and gravel resource areas are first delineated by geological boundaries and then classified into three levels of significance: primary, secondary, and tertiary. Each area of primary significance is given a deposit number and all such deposits are shown by dark red shading on Maps 2A, 2B and 2C.

Selected Aggregate Resource Areas of primary significance are not permanent, single land use units. They represent areas in which a major resource is known to exist and may be reserved wholly or partially for extractive development and/or resource protection.

Deposits of secondary significance are indicated by light red shading on Maps 2A, 2B and 2C. Such deposits are believed to contain significant amounts of sand and gravel. Although deposits of secondary significance are not considered to be the "best" resources in the report area, they may contain large quantities of sand and gravel and should be considered as part of the aggregate supply of the area.

Areas of tertiary significance are outlined on the maps by a solid line but have no shading. They are not considered to be important resource areas because of their low available resources, or because of possible difficulties in extraction. Such areas may be useful for local needs but are unlikely to support large-scale development.

The process by which deposits are evaluated and selected involves the consideration of two sets of criteria. The main selection criteria are site specific, related to the characteristics of individual deposits. Factors such as deposit size, aggregate quality, and deposit location and setting are considered in the selection of those deposits best suited for extractive development. A second set of criteria involves the assessment of local aggregate resources in relation to the quality, quantity, and distribution of resources in the region in which the report area is located. The intent of such a process of evalution is to ensure the continuing availability of sufficient resources to meet possible future demands.

SITE SPECIFIC CRITERIA

Deposit Size

Ideally, selected deposits should contain available sand and gravel resources large enough to support a commercial pit operation using a stationary or portable processing plant. In practice, much smaller deposits may be of significant value depending on the overall reserves in the rest of the municipality. Generally, deposits in Class 1, i.e. those thicker than 20 feet (6 m), and containing more than 35 percent gravel are considered to be most favourable for commercial development. Thinner deposits may be valuable in municipalities with low total resources.

Aggregate Quality

The limitations of natural aggregates for various uses result from variations in the lithology of the particles composing the deposit, and from variations in the size distribution of these particles.

Four indicators of the quality of aggregate may be included in the symbol for each deposit on Maps 1A, 1B and 1C. They are: gravel content (G or S); fines (C); oversize (O); and lithology (L).

Three of the indicators deal with grain size distribution. The gravel content (G or S) indicates the suitability of aggregate for various uses. Deposits containing at least 35 percent gravel in addition to a minimum of 20 percent material greater than the 26.5 mm sieve are considered to be the most favourable extractive sites, since this content is the minimum from which crushed products can be economically produced.

Excess fines (high silt and clay content) may severely limit the potential use of a deposit. Fines content in excess of 10 percent may impede drainage in road sub-base aggregate and render it more susceptible to the effects of frost action. In asphalt aggregate, excess fines hinder the bonding of particles. Deposits known to have a high fines content are indicated by a "C" in the quality portion of the Deposit Symbol.

Deposits containing more than 20 percent oversize material (greater than 4 inches (10 cm) in diameter) may also have use limitations. The oversize component is unacceptable for all concrete aggregate and for road-building aggregate, so it must be either crushed or removed during processing. Deposits known to have an appreciable oversize component are indicated by an "O" in the quality portion of the Deposit Symbol.

The other indicator of the quality of an aggregate is lithology. Just as the unique physical and chemical properties of bedrock types determine their value for use as crushed rock, so do various lithologies of particles in a sand and gravel deposit determine its suitability for various uses. The presence of objectionable lithologies such as chert, siltstone, and shale, even in relatively small amounts, can result in a reduction in the quality of an aggregate, especially for high quality uses such as concrete and asphalt. Similarly, highly weathered, very porous and friable rock can restrict the quality of an aggregate. Deposits known to contain objectionable lithologies are indicated by an "L" in the quality component of the Deposit Symbol.

If the Deposit Symbol indicates either "C", "O", or "L" or any combination, the quality of the deposit is considered to be reduced for some uses of the aggregate. No attempt has been made to quantify the degree of limitation imposed. Assessment of the four indicators is made from published data, from data contained in files of both the Ontario Ministry of Transportation and Communications and the Engineering and Terrain Geology Section of the Ontario Geological Survey, and from field observations.

Analyses of unprocessed samples obtained from test holes, pits or sample sites have been plotted on grain size distribution graphs. On the graphs are the gradation specification envelopes for Ontario Ministry of Transportation and Communications' products: Granular Base Course A, B and C; and Hot-Laid Asphaltic Sand Nos. 1, 2, 3, 4 and 8; and concrete sand. By plotting the gradation curves with respect to the specification envelopes, it can be determined how well the unprocessed sampled material meets the criteria for each product. In addition, Los Angeles abrasion, absorption and Magnesium Sulphate soundness tests along with petrographic analyses were performed on selected samples, the results of which are included in Appendix D.

Location and Setting

The location and setting of a resource area has a direct influence on its value for possible extraction. The evaluation of a deposit's setting is made on the basis of natural and man-made features which may limit or prohibit extractive development.

First, the physical context of the deposit is considered. Deposits with some physical constraint on extractive development, such as thick overburden or high water table, are less valuable resource areas because of the difficulties involved in resource recovery. Second, permanent man-made features, such as roads, railways, powerlines, and housing developments, which are built on a deposit, may prohibit its extraction. The constraining effect of legally required setbacks surrounding such features is included in the evaluation. A quantitative assessment of these constraints can be made by measurement of their areal extent directly from the topographic maps. The area rendered unavailable by these features is shown for each resource area in Table 3 (Column 3).

The assessment of sand and gravel deposits with respect to local land use and to private land ownership is an important component of the general evaluation process. These aspects of the evaluation process are not considered further in this report, but readers are encouraged to discuss them with personnel of the pertinent District Office of the Ontario Ministry of Natural Resources.

REGIONAL CONSIDERATIONS

In selecting sufficient areas for resource development, it is important to assess both the local and the regional resource base, and to forecast future production and demand patterns. Although an appreciation of the regional context is required to develop comprehensive resource management techniques, such detailed evaluation is beyond the scope of this report. The selection of resource areas made in this study is based primarily on geological data or on considerations outlined in preceding sections.

BEDROCK RESOURCES

The Precambrian Shield rocks in northern Ontario are generally more complex and variable than the Paleozoic rocks of southern Ontario. They often show wide variations in mineralogy, texture (grain size), joint patterns and degree of weathering, even within specific rock types and over relatively short distances. As these factors are considered important in determining the suitability of the bedrock for use as aggregate, the aggregate potential may also vary considerably from location to location.

Careful selection is especially important if the bedrock is to be used as concrete aggregate. Deleterious chemical reactions may develop in the concrete which can lead to its eventual deterioration. Fortunately, these chemical reactions should not influence the use of bedrock-derived aggregate for such uses as road-base material. However, highly weathered, very porous and friable rock should be avoided for all uses.

For these reasons, no specific bedrock resources have been selected for resource protection. A summary, however, of the bedrock resources on a regional level is included in the Bedrock Geology and Resource Potential section.

Part III — Assessment of Aggregate Resources in the Hemlo Area

LOCATION AND POPULATION

The report area is located midway between Sault Ste. Marie and Thunder Bay near the north shore of Lake Superior. It occupies approximately 570,000 acres (230 700 ha) in the Districts of Thunder Bay and Algoma. Included within the area are the municipalities of Marathon, Manitouwadge and White River which form the western, northern and eastern limits of the study area, respectively. The area is covered by the Cedar Lake (42 C/12), Caldwell Lake (42 D/15), Goodchild Lake (42 D/16), Kwinkwaga Lake (42 C/14), Manitouwadge (42 F/4), Marathon (42 D/9), White Lake (42 C/13) and White River (42 C/11) map sheets of the National Topographic System, at a scale of 1:50 000.

Because of the large extent of the report area, it has been subdivided into three separate map areas. The Marathon Map Area consists of Marathon Township Municipality along with Pic, Lecours, Bomby and Brothers Townships. Also included is an unsurveyed area located in the northeastern part of the map area. Manitouwadge Township Municipality and a considerable area of unsurveyed land to the south make up the Manitouwadge Map Area. Included within the White River Map Area are Laberge, Bryant, McCron, Cecile and Knowles Townships as well as White River Township Municipality. The northwest corner of this map area is unsurveyed.

The municipalities of Marathon, Manitouwadge and White River, whose 1982 population figures are 2252, 3069 and 975, respectively, are the major population centres in the area (Ontario Ministry of Municipal Affairs and Housing 1984). Other smaller settlements include Heron Bay as well as Pic and Pic-Mobert Indian Reserves. Trailer camps located in the vicinity of the Hemlo mine sites provide temporary housing. In the remainder of the report area the population is scarce. Major activities in the area include forestry and mining. A pulp and paper mill is located at Marathon and logging and sawmill operations exist at White River and Manitouwadge. The Geco mine is a major employer at Manitouwadge. Recreation centres in the area include White Lake Provincial Park and Pukaskwa National Park.

The report area is also the site of the most important recent gold discovery in Canada. The discovery of large gold deposits near Hemlo in 1981 initiated a flurry of exploration activity in the area which continues today. Three mines are presently in the process of development which involves the construction of mine shafts, mills and service buildings. Construction during the initial stages of mine development has already placed a great demand on local aggregate resources and this demand is expected to increase as the development continues. Additional quantities of aggregate may be required for road building and the establishment of service industries in the vicinity as well as for use as mine backfill.

As a result of the mining development at Hemlo, the municipalities in the area expect their population to increase significantly. To accommodate this population growth the municipalities are currently in the process of developing residential lots and expect additional residential expansion. Marathon and Manitouwadge expect the majority of this growth to occur in their municipalities as they are closer to the site of the new mine developments. These two municipalities have constructed airports and expect additional development from the establishment of service industries for the mines. As a result of this development, the demand for sand and gravel in the vicinity of the municipalities is expected to increase.

The project area flanks King's Highway 17 and Secondary Highway 614, the major transportation routes in the area. King's Highway 17 forms part of the Trans Canada Highway and links the Hemlo Area to population centres in northern and southern Ontario. Highway 614 provides access between Manitouwadge and King's Highway 17. Other secondary highways in the report area include Highways 626, 627 and 631. Access is also provided by bush and logging roads which branch off these highways. Generally, the accessibility decreases as the distance from the highways increases, and a considerable proportion of the Hemlo Area is presently inaccessible via road. Two lines of the Canadian Pacific Railway traverse the area parallel to Highways 17 and 614.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

The physiography and distribution of unconsolidated sediments, including sand and gravel deposits, are largely the result of glacial activity during the Wisconsinan Stage of the Pleistocene Epoch, informally known as the 'Great Ice Age'. This stage, which lasted from approximately 100 000 to 7000 years ago, was marked by the repeated advance and melting back of massive, continental ice sheets.

The surficial geology of the area has been evaluated at a reconnaissance level by Boissonneau (1965) and Zoltai (1965), and in engineering geology terrain studies by Gartner and McQuay (1979; 1980a; 1980b). R.S. Geddes and A.F. Bajc, who assisted in this aggregate inventory, have undertaken detailed Quaternary geology mapping of the White Lake and Cedar Lake map areas (Geddes and Bajc 1985a; 1985b). F.J. Kristjansson of the North Central Region, Ontario Ministry of Natural Resources, provided Quaternary geology mapping for the municipalities of Marathon, Manitouwadge and White River.

Till is the oldest surficial sediment in the Hemlo Area and was deposited as the ice advanced to the southwest. The till generally occurs as a thin veneer over bedrock, although at several localities a considerable thickness was observed. It varies in composition between a silt till and a stony sand till, and may be carbonate rich. Till is generally not well suited for aggregate use as it often contains excess fines and abundant oversize clasts. However, it has been extracted for use as fill at several locations, notably in the central part of the report area. The silt till in the area may also be suitable for applications such as tailings dam construction. For detailed descriptions of the till in the area the reader is referred to Geddes (1984) and Geddes and Bajc (1985a; 1985b).

Much of the topography in the Hemlo Area is controlled by bedrock, and many of the glacial deposits are situated in depressions between bedrock knobs. Such is the case with the esker deposits which form segmented, sinuous ridges in the report area. These ridges rise between 15 and 65 feet (5 and 20 m) above the surrounding terrain and are often flanked by kettle depressions. They were deposited by meltwaters flowing in tunnels under the ice or in re-entrants at the ice front and consist of stratified sand and gravel. The eskers trend in a general north to south or northeast to southwest direction and contain a significant proportion of the report area's potential resources of crushable gravel.

Several deposits of ice-contact stratified drift were deposited in close proximity to the ice front as it retreated northward. The origin of these complex features can be attributed to a variety of depositional environments and many of these deposits are associated with esker systems. These features are typified by a hummocky topography. Ice-contact sand and gravel has been extracted from numerous pits in the Hemlo Area for road-building and construction aggregate.

The outwash features in the Hemlo Area were deposited by meltwaters flowing in bedrock depressions beyond the ice margin. The outwash generally consists of well stratified sand and gravel. The outwash deposited in close proximity to the ice front, such as that associated with esker systems, usually contains coarser material which is better suited for aggregate use. Sand is the predominant sediment exposed in outwash that has been deposited further away from the ice margin. The deposits along the banks of the White River and the shore of White Lake consist of this finer outwash.

During the withdrawal of the ice which occupied the Pic River valley, meltwaters flowing into a lake occupying the Lake Superior basin deposited a broad glaciolacustrine delta near Marathon. The surface of this deposit is relatively flat while the edges are often steep sided and in excess of 200 feet (61 m) high. Unlike most of the glacial features in the Hemlo Area, the delta was deposited on a bedrock high. Material exposed in this delta ranges from well stratified sand to coarse gravel which is well suited for a variety of aggregate uses (Cowan 1976). Another glaciolacustrine delta was deposited near the mouth of the Pic River. However, this delta was formed when lake levels were lower and consists dominantly of sand suitable for low-specification aggregate uses.

As the ice margin retreated further northwards, waters of ancestral Lake Superior, which were initially considerably higher than present lake levels, inundated the Black and Pic River valleys. In the deep waters of this lake, massive and/or varved silt and clay were deposited. Glaciolacustrine plain sediments consisting largely of silty fine sand were deposited as water levels lowered. These shallow water sands usually overlie the deep water sediments except in areas along the edge of the basins where silts and clays are often exposed at the surface. The glaciolacustrine deposits, associated with ancestral Lake Superior, generally occur below 1050 feet (320 m) above sea level (a.s.l.). In places, this glaciolacustrine material overlies esker and ice-contact features. The glaciolacustrine sand is generally too fine for most aggregate uses except fill.

Glaciolacustrine fine sands were also observed at elevations higher than 1050 feet (320 m) a.s.l. near White Lake, Cedar Lake and the municipality of White River. However, these deposits are considered to be part of separate, smaller proglacial lake basins not related to ancestral Lake Superior.

As the water level lowered in ancestral Lake Superior, wave action reworked existing deltaic and ice-contact deposits forming glaciolacustrine beaches. The best developed of these beaches occurs along the frontal section of the delta at Marathon. Glaciolacustrine beach sediments are also exposed in several deposits located south of Barehead Lake, along Highway 614. The well stratified sand and gravel contained within the glaciolacustrine beaches is generally well suited for aggregate use.

Postglacial deposition of sand dunes and alluvium as well as the development of numerous swamps has also modified the physiography of the Hemlo Area. Dune sand is especially abundant along the shore of Lake Superior near Marathon. Other eolian deposits are located northeast of Manitouwadge near Wowun Lake, east of White Lake and along the Black River valley. Alluvium occurs chiefly along the courses of existing creeks and rivers, while poor drainage in many depressions has led to the development of extensive swamp lands.

EXTRACTIVE ACTIVITY

Numerous sand and gravel pits have been opened in the Hemlo Area. The majority of these have been developed along Highways 17 and 614 as well as near Marathon, Manitouwadge and White River. Most of the pits are worked on a demand basis in response to road-building and construction projects in the area. During field investigations in 1983 and 1984 for this project, several pits were actively being extracted or showed signs of recent extraction, largely in response to increased demands for aggregate in the three municipalities and in the vicinity of the Hemlo mine developments. Near Hemlo, sand and gravel extraction and exploration activities were intense and a number of pits were recently opened or in the process of development. In addition, a granodiorite quarry was established for aggregate production near the junction of Highways 17 and 614. As development at the Hemlo mine site and the municipalities continues, future extractive activity in the report area is expected to increase substantially.

AGGREGATE QUALITY AND SUITABILITY

During field investigation 46 samples were taken from existing pit faces and test pits. The samples were analyzed for grain size distribution (Figures 3a to 17b) and four aggregate quality tests were performed on each of thirty selected samples. The results of these tests are portrayed in Appendix D and include Los Angeles abrasion, absorption and Magnesium Sulphate soundness tests along with petrographic analyses. The samples were analysed in either the laboratories of the Soils and Aggregates

Section, Engineering Materials Office, Ontario Ministry of Transportation and Communications or in the Geoscience Laboratories, Geoservices Section, Ontario Geological Survey.

In general, the aggregate in the study area is considered hard and durable and of sufficient quality for uses including granular base course and 16 mm crushed products. The results from the four quality tests, for the most part, fall within the Ontario Ministry of Transportation and Communications (M.T.C.) specification limits for these products. For hot-laid asphalt and concrete, however, petrographic numbers range from acceptable to unsuitable. The presence of chert is the major limiting factor with respect to petrographic quality. Chert is an objectionable material as, over time, it can react with cement and cause cracking of concrete as well as result in popouts in both concrete and asphalt surfaces (Rogers 1983).

The sand and gravel in the Hemlo Area contains chert transported by glacial ice from the Palaeozoic rocks of the James Bay Lowlands. Chert contents in the tested samples range from 0 to 14.4 percent. The chert tends to be concentrated in the medium sand to fine gravel component of the aggregate. Samples in which the gravel fraction consists predominantly of fine gravel have consistently higher chert contents than samples containing coarser gravel. Chert contents also tend to increase towards the north with significantly higher percentages being observed near Manitouwadge. Deterioration of concrete structures containing chert in Manitouwadge and vicinity has been reported by M.T.C. For this reason, the deleterious lithology quality indicator has been placed on deposit symbols in the Manitouwadge area. Because of the variability encountered in chert contents elsewhere in the area, it is recomended that specific sites for extraction of high-specification aggregate be tested prior to development.

SELECTED SAND AND GRAVEL RESOURCE AREAS

Maps 1A, 1B and 1C for the Marathon, Manitouwadge and White River Map Areas, respectively, indicate the deposits which contain granular materials. These deposits occupy a total of approximately 132,000 acres (53 000 ha) and contain an original resource tonnage of 4900 million tons (4450 million tonnes). Many of these resource areas have limited extraction potential because of the restricted amount of available resources, quality of the material and/or accessibility. Consequently, only the most significant sources are suggested for possible resource protection. The aggregate resources in parts of the report area have been previously described by Gartner Lee Associates Limited (1974), Cowan (1976) and Gartner and McQuay (1979; 1980a; 1980b).

Considerable sand and gravel resources have been selected at both the primary and secondary levels within Marathon Township Municipality. The aggregate in this area is considered well suited for extractive development and many of the deposits have been traditional aggregate sources. Between Marathon and the mining developments near Hemlo, however, high quality aggregate resources are lacking and the predominant glacial sediment is glaciolacustrine fine sand.

Selected Sand and Gravel Resource Areas 5, 6, 7, 8, 9 and 15 are located within a 20-kilometre radius of the Hemlo mining camp. The material exposed in these areas varies from sand to coarse gravel of esker, ice-contact and outwash origins. The Primary Resource Areas, together with several deposits selected at the secondary level in the area, contain significant resources of sand and gravel suitable for such uses as mine backfill, road base and crushed stone.

The areas selected for possible resource protection in Manitouwadge Township Municipality include several esker, ice-contact and outwash deposits. The material available for extraction in these deposits ranges from sand to coarse gravel suitable for a variety of aggregate uses. South of the municipality, five locally significant glaciolacustrine reworked ice-contact deposits along Highway 614 appear to be suitable sources of at least low-specification aggregate. Southeast of these deposits, five esker ridges which constitute Resource Area 10 and several flanking ice-contact deposits are considered valuable future sources of aggregate.

West of the municipality of White River, large possible resources of sand and gravel are available from glaciofluvial deposits which trend northeast to southwest across Cecile and Knowles Townships. In addition, six locally significant deposits have been selected in Laberge, Bryant and McCron Townships. Within the municipality of White River, a prominent esker has been selected at the primary level of significance. This esker has been a traditional source of aggregate in the municipality. Also, several deposits designated as secondary resources are suitable for local aggregate uses in the municipality.

Despite the perceived lack of aggregate in the early stages of development of the Hemlo camp, the aggregate resources selected for possible resource protection appear adequate to meet most mine construction and municipal demands within the project area. Also, many deposits in more remote areas or in areas experiencing lower demands for aggregate are considered important future sources of sand and gravel.

The Selected Sand and Gravel Resource Areas of Primary Significance occupy a total available area of 8500 acres (3450 ha). They contain possible sand and gravel resources of approximately 670 million tons (610 million tonnes). The selected areas contain most of the potential resources of crushable gravel in the study area.

SELECTED SAND AND GRAVEL RESOURCE AREAS, MARATHON MAP AREA (MAP 2A)

Selected Sand and Gravel Resource Area 1

Selected Sand and Gravel Resource Area 1 consists of seven glaciolacustrine delta deposits, designated 1a to 1g on Map 2A, in Marathon Township Municipality. Resource Area 1 contains large potential resources of sand and gravel and has been a traditional source of aggregate in the municipality.

Areas 1a to 1c have been classified as gravel sources. Deep kettle depressions exist in these deposits, notably in Area 1c where they exceed 200 feet (61 m) in depth. Five pits have been opened in Areas 1a and 1b. Faces in these pits expose between 10 and 25 feet (3 and 8 m) of fine to coarse gravel with a coarse sand matrix. A sample taken from pit no. 11 contained 71 percent gravel (Figure 3a). Test holes placed in the vicinity of pit nos. 11, 12 and 25 by M.T.C. also revealed high gravel contents. The aggregate extracted from these pits is crushable and suitable for a range of construction products including granular base course, Hot-Laid (H.L.) No. 4 stone and structural concrete stone. Sand control may be required in sections for Granular Base Course (G.B.C.) A and blending may be necessary for the production of hot-laid and concrete sand. Oversize clasts which are abundant in Area 1a should be removed or crushed in a primary crusher. In places, the gravel in the resource area may be coated with fines as was observed in pit no. 11.

Unlike Areas 1a and 1b, subsurface data are presently lacking for Area 1c and road access is limited. However, Area 1c was deposited in a similar geological environment, as Areas 1a and 1b, and gravel was observed on the surface of kettle depressions in the deposit. Therefore, the aggregate in Area 1c is expected to have similar potential.

Sand is the predominant material exposed on the relatively flat surfaces of Areas 1d to 1g. Four pits have been developed in these areas. Faces in the pits reveal 4 to 25 feet (1.2 to 8 m) of gravelly sand, generally suitable for pit-run products. Blending would probably be required for high-specification sand products. In places within these areas, the sand may overlie and mask coarser aggregate. Gravel pockets observed in the floor of pit no. 8 are suitable for use as G.B.C. A, H.L. 4 stone and structural concrete stone. In test holes HE-TH-1 and HE-TH-2, 2 to 2.5 feet (60 to 80 cm) of sand overlies medium to coarse gravel. The aggregate sampled from these test holes contained between 39 and 56 percent gravel (Figure 6a). A 5-foot (1.5 m) thick gravel seam was also encountered beneath 1.5 feet (46 cm) of sand in test hole HE-TH-3. Further investigation of Areas 1d to 1g may uncover additional quantities of gravel.

Ten geophysical traverse lines were placed in Areas 1a, 1b and 1f. Eight of these lines indicated the possibility that aggregate extends to a considerable depth. Bedrock surfaces were encountered at depths of 24 feet (7 m) and 34 feet (10 m) beneath lines HE-GT-12 and HE-GT-2 (floor of pit no. 11), respectively. For Areas 1a to 1d and Area 1f, average deposit thicknesses have been estimated at 40 feet (12 m) based on the potential depth of extraction. Lower thickness values have been estimated for Areas 1e and 1g, reflecting a greater degree of bedrock control.

Resource Area 1 occupies 3800 acres (1540 ha). Cultural constraints and previous extraction reduce the area currently available to 3200 acres (1300 ha). Assuming average deposit thickness values ranging from 19 to 40 feet (6 to 12 m), available sand and gravel resources are estimated to total 305 million tons (275 million tonnes). Access to the resource area via Highway 17 and bush roads is good with the exception of Areas 1c and 1g. The development of an airport in Area 1d may inhibit extractive development in its vicinity.

Selected Sand and Gravel Resource Area 2

Two ice-contact deposits (Areas 2a and 2b) located near Three Fingers Lake in Marathon Township Municipality have been selected at the primary level of significance. The deposits are hummocky features situated in a bedrock depression. Although subsurface data are scarce for these deposits, sandy, fine to coarse gravel was observed at several localities at the surface. Also, a water well along Three Fingers Lake indicates the presence of 70 feet (21 m) of sand and gravel. This depth may not reflect the possible depth of extraction as numerous lakes in Area 2b indicate a potentially high water table and the depth to bedrock may be variable. Therefore, an average thickness value of 19 feet (6 m) has been estimated for Area 2.

Resource Area 2 occupies 285 acres (115 ha), of which 225 acres (91 ha) are presently available for extraction. Assuming an average thickness of 19 feet (6 m), resources of sand and gravel are estimated to be 11 million tons (10 million tonnes). Access in Resource Area 2 is provided by Highway 17 and gravel-surfaced roads.

Selected Sand and Gravel Resource Area 3

Selected Sand and Gravel Resource Area 3 consists of two glaciolacustrine beach deposits (Areas 3a and 3b) which were formed by reworking of the frontal section of the glaciolacustrine delta (Resource Area 1) near Marathon (Cowan 1976). A sequence of beach terraces were formed on the 50- to 200-foot (15 to 61 m) slopes of the resource area. These terraces represent different shoreline stages of ancestral Lake Superior. The predominant material exposed on the surface of these deposits is medium to coarse sand with minor amounts of fine gravel. Gravel beds, however, were observed occasionally on the surface and concentrations of gravel may be present at depth.

Four pits have been opened in Area 3. Pit no. 7 has been developed in Area 3a. The 10- to 20-foot (3 to 6 m) faces in this pit expose well stratified medium to coarse sand with minor fine gravel. M.T.C. reports that the material extracted from the pit is generally acceptable for G.B.C. C but blending would be required for higher specification sand products. The 20- to 30-foot (6 to 9 m) faces of pit no. 14, developed in Area 3b, reveal 3 to 5 feet (1 to 1.5 m) of coarse sand over interbedded sand and fine to medium gravel layers. Faces in the remaining pits in the resource area are generally slumped and overgrown.

In the northern part of Area 3b, subsurface data indicate a variable thickness of aggregate over bedrock. Six test holes placed by Ontario Hydro Research at a transformer station just south of pit no. 15 indicated between 20 and 27 feet (6 and 8 m) of aggregate over bedrock. The sediments revealed in one of these test holes are as follows:

- 1.2 feet (0.4 m) of fine to medium sand over
- 7.0 feet (2.1 m) of coarse sand and some fine gravel over
- 6.7 feet (2.0 m) of coarse sand with abundant fine to coarse gravel over
- 5.8 feet (1.8 m) of fine to medium sand with some fine to coarse gravel over bedrock.

Water wells in this area indicate aggregate thicknesses of between 23 and 93 feet (7 and 28 m) over bedrock. Considerably higher amounts of sand and gravel may be available from the southern part of Area 3b. Up to 200 feet (61 m) of slumped aggregate is exposed in pit no. 24 and seismic line HE-GT-9 indicates a minimum of 40 feet (12 m) of granular materials. Although a deposit thickness estimate of 30 feet (9 m) has been adopted for Area 3b, in places the depth of available aggregate may be greater.

Selected Resource Area 3 totals 1680 acres (680 ha) of which 1500 acres (610 ha) are currently available for extraction. Assuming an average thickness of 20 and 30 feet (6 and 9 m) for Areas 3a and 3b, respectively, available aggregate resources are estimated to be 112 million tons (102 million tonnes). Access in the resource area is good with the exception of the southern part of Area 3b.

Selected Sand and Gravel Resource Area 4

A glaciolacustrine beach deposit located adjacent to Marathon has also been selected at the primary level. Five pits have been opened in this deposit. Faces in pit no. 18 exposed 4 feet (1.2 m) of coarse sand over 11 feet (3 m) of sandy gravel. The lower gravel unit was sampled and contained 58 percent gravel, 40 percent sand and 2 percent fines (Figure 3a). High gravel contents were also revealed in pit nos. 19, 20 and 21. M.T.C. has tested the aggregate in pit no. 19 and reports that it is generally suitable for use as concrete stone, H.L. 4 stone, 16 mm crushed stone and granular base course. Sand control may be required in places for crushing, and blending would be necessary for higher specification sand products. In pit no. 21 the glaciolacustrine beach gravel is overlain by approximately 9 feet (3 m) of dune sand.

In the undeveloped parts of the deposit, notably south of the pits, sand is the predominant material exposed at the surface. However, this sand may mask underlying gravel deposits as was observed in pit no. 18. Three hammer seismic lines were placed on the deposit. Data for line HE-GT-6 indicates the presence of the water table 5 feet (1.5 m) beneath the floor of pit no. 18. Line HE-TH-7 indicates the possibility that sand and gravel extends to a considerable depth. Fifteen feet (5 m) of aggregate over bedrock is suggested by line HE-GT-8.

Resource Area 4 comprises 300 acres (121 ha). Cultural constraints and previous extraction reduce the area presently available to 225 acres (91 ha). This acreage may be further reduced by future expansion of the community of Marathon. Assuming a deposit thickness of 15 feet (5 m), resources are estimated to be 8 million tons (7 million tonnes).

Selected Sand and Gravel Resource Area 5

Four deposits located in Bomby Township are included in Resource Area 5. The ice-contact deposit north of Molson Lake has been designated as Area 5a. The deposit exhibits hummocky relief and is predominantly a sand source. Four pits have been developed in the deposit. Faces in pit nos. 42 to 44 range in height from 20 to 25 feet (6 to 8 m) and expose largely fine to medium sand with minor amounts of fine gravel. Higher concentrations of gravel were observed in pit no. 45 and the floor of pit no. 44. In pit no. 45, up to 30 feet (9 m) of interbedded layers of medium to coarse sand and sandy gravel is exposed. A sample taken of this material contained 33 percent gravel, 64 percent sand and 3 percent fines (Figure 5a). Limited amounts of crushed stone may be produced from localized gravel accumulations with selection and sand control measures. Factors limiting use include the excessive fineness of the sand in sections and the presence of occasional silt seams. Also, the aggregate may contain muscovite particles, derived from the local bedrock, which do not bond well with cement mixes. Bedrock is exposed in the floors of pit nos. 44 and 45 which restricts extraction depth.

Two esker ridges, which have local relief varying from 25 to over 50 feet (8 to over 15 m), make up Area 5b. Although the eskers are limited in extent, they are considered to contain locally significant resources of gravel. A shallow test pit was placed in one of these ridges exposing medium to coarse gravel with coarse sand matrix. It should be noted that the two esker deposits are joined by a small esker ridge, too limited in size to delineate on the maps.

Area 5c is a relatively flat outwash deposit consisting predominantly of sand. In the northern part of the area the material consists of medium to coarse sand with minor amounts of fine gravel. Towards the south the aggregate becomes slightly finer and is largely medium sand. The grain size distrbution of a sample (HE-SS-1) of the sand is displayed in Figures 7a and 7b.

Resource Area 5 is situated in close proximity to the recent mining developments at Hemlo where the demand for aggregate is high. Considerable resources of sand will be required to meet present and future demands for uses such as mine backfill. Both Areas 5a and 5c are potential backfill sources. The esker ridges of Area 5b represent potential sources of crushable gravel which is also in high demand. Resource Area 5 totals 670 acres (270 ha), of which 620 acres (250 ha) are presently available for extraction. Assuming average thicknesses ranging from 25 to 35 feet (8 to 11 m) for the deposits, available resources of sand and gravel are estimated to be 53 million tons (48 million tonnes).

Selected Sand and Gravel Resource Area 6

Selected Sand and Gravel Resource Area 6 consists of two esker segments and associated ice-contact deposits which are located north of Bomby Township near Philips Creek. The esker ridges, designated as Area 6a, rise between 25 and 45 feet (8 and 14 m) above the surrounding terrain. Three pits have recently been developed in the esker ridges. The material exposed in the 10- to 25-foot (3 to 8 m) high faces in these pits is dominantly fine to coarse gravel although sand pockets occur locally. The gravel quality is variable as pockets of poorly sorted gravel coated with fines are common. Silt layers are occasionally present in sand pockets and oversize clasts are abundant. Although gravel quality is variable, with selective extraction and processing it is expected that a variety of aggregate products, including crushed stone, can be produced.

The ice-contact deposits (Area 6b) are predominantly sand sources, although gravel may occur locally. One pit (pit no. 52) has been opened in these deposits. Faces in the pit range from 10 to 20 feet (3 to 6 m) and expose very fine sand to coarse sand with some fine gravel. A sample taken of this material contained 23 percent fine gravel, 75 percent sand and 2 percent fines (Figure 5a). Silt and clay seams were observed in the pit which should be avoided upon extraction. A pocket of coarse gravel was also observed in the pit and additional gravel accumulations may be present in the undeveloped part of Area 6b.

At the time of field investigation, aggregate was actively being extracted from Resource Area 6 for use in the Hemlo mining development. A total of 106 acres (43 ha) were considered available for extraction in Resource Area 6. Assuming average depths of 30 and 15 feet (9 and 5 m) for Areas 6a and 6b, respectively, resource tonnages were estimated to be 4 million tons (4 million tonnes).

Selected Sand and Gravel Resource Area 7

Selected Sand and Gravel Resource Area 7 is made up of two esker segments (Area 7a) and a flanking ice-contact deposit (Area 7b). The deposits are situated just east of Highway 614 near the northern boundary of the Marathon Map Area. During field investigation a shallow test pit was excavated on the crest of the 20- to 25-foot (6 to 8 m) high southernmost esker ridge. The gravel exposed in this test pit appeared suitable for the production of a variety of aggregate products including crushed stone. Similar quality aggregate is expected to exist in the northernmost esker segment. The ice-contact deposit likely consists of finer material than that in the esker ridges.

Resource Area 7 occupies approximately 37 acres (15 ha) currently available for extraction. Assuming average deposit thicknesses of 25 feet (8 m) and 15 feet (5 m) for Areas 7a and 7b, respectively, sand and gravel resources total 2 million tons (2 million tonnes). Although the amount of aggregate available from the deposits is limited relative to other deposits selected at the primary level, the area is considered important as it is located within a reasonable trucking distance to the Hemlo mining camp and near highway access.

Selected Sand and Gravel Resource Area 8

Four esker segments located west of Highway 614 near the northern boundary of the Marathon Map Area are included in Resource Area 8. The esker material is buried beneath a variable thickness of glaciolacustrine fine sand. In pit no. 66, this fine sand veneer ranges in thickness from 6 feet (1.8 m) at the esker crest to over 12 feet (4 m) along the flanks. The underlying esker material, exposed in the 50- to 65-foot (15 to 20 m) faces of the pit, consists dominantly of clean sand with fine gravel. This material was sampled and contained 29 percent gravel and 71 percent sand (Figure 5a). A 5-foot (1.5 m) thick seam of medium to coarse gravel was also observed in the pit with an estimated gravel content of 60 percent. Similar materials were observed in pit no. 65. During field investigation the pits were being utilized for logging road construction in the area.

In the undeveloped parts of the esker segments, fine-grained glaciolacustrine sediments mask the nature of the underlying esker material. Although the deposits have been classified as sand sources, based on the pit exposures, additional quantities of coarser gravel similar to the seam exposed in pit no. 66 likely exist. Therefore, further subsurface investigation in the resource area may increase its total resource potential.

The esker segments occupy approximately 44 acres (18 ha) currently available for extraction. Assuming an average thickness of 50 feet (15 m), aggregate resources total 6 million tons (5 million tonnes). Access to Resource Area 8 is provided by a recently constructed logging road which branches off Highway 614 near Agonzon in the Manitouwadge Map Area.

Sand and Gravel Resource Areas of Secondary Significance, Marathon Map Area

Three glaciolacustrine beach deposits adjoining Resource Area 3b in Marathon Township Municipality have been selected at the secondary level. Sandy aggregate, similar to that described for Resource Area 3b, is the predominant material exposed on the surface of these deposits. The deposits differ from Area 3b, however, in that bedrock is expected to be closer to surface. A potentially high water table in the southernmost deposit may also limit the amount of available aggregate.

In addition, three ice-contact deposits and part of a fourth have also been selected at the secondary level within the municipality. Two pits have been opened in the deposits which flank the Pic River in the northeastern part of the municipality. Faces in the pits expose between 10 and 20 feet (3 and 6 m) of sand and gravel suitable for local construction uses. A thin layer of silt and clay may overlie the aggregate in the southern deposit. The ice-contact deposit adjoining Resource Area 2a is considered to consist of similar material as that in Area 2a. An irregular bedrock surface is expected to underlie the deposit, however, restricting the amount of available aggregate. Two pits have been developed in the ice-contact deposit along the southern border of the municipality. Faces in pit no. 27 range from 20 to 30 feet (6 to 9 m) high and reveal irregularly bedded fine to coarse gravel. M.T.C. reports the aggregate is generally acceptable for use as 16 mm Crushed Type A and granular base course. In sections, sand control would be required for crushing and a large clay pocket was observed in the pit which should be avoided. Although this deposit is considered a source of quality aggregate, the quantity of available aggregate is limited by residential development at the community of Heron Bay.

A small ice-contact deposit which has been reworked by wave action in a glacial lake is situated along King's Highway 17 in Pic Township. Although the pit developed in this deposit is considered depleted, the western part of the deposit remains undeveloped. Three test holes have been placed in this area by M.T.C. They uncovered up to 15 feet (5 m) of fine to coarse sand with interbedded gravel layers. This material is generally suitable for use as H.L. 4 stone, 16 mm crushed stone and granular base course. Silt and clay seams are occasionally present which should be avoided and blending would be required for high-specification sand products. A seismic line (HE-GT-16), placed on the deposit, indicates approximately 18 feet (5 m) of aggregate overlying bedrock.

The remaining deposits selected at the secondary level are located in the unsurveyed, northeastern part of the map area. An ice-contact and small esker deposit are situated west of Amwri Lake. These deposits are considered to consist of a variable thickness of gravelly aggregate over bedrock or till. The material would likely be suitable for local construction uses and higher concentrations of gravel may exist in the esker segment. Similar to the esker ridges of Resource Area 8, the flanking ice-contact deposits are overlain by a variable thickness of fine-grained glaciolacustrine sediments. These sediments mask the nature of the underlying ice-contact material and further investigation would be required to determine the quality of the material. Nevertheless, the deposits are considered to contain significant resources of at least sandy aggregate as indicated by a hummocky topography and several deep kettle depressions. The northernmost of these deposits extends into the Manitouwadge Map Area.

Descriptions of the ice-contact deposit north of Amwri Lake and the outwash deposit near Petrand Lake, along the northern boundary of the map area, will be included in secondary resource discussions of the Manitouwadge Map Area.

SELECTED SAND AND GRAVEL RESOURCE AREAS, MANITOUWADGE MAP AREA (MAP 2B)

Selected Sand and Gravel Resource Area 9

Three esker ridges in the southwestern part of the Manitouwadge Map Area constitute Selected Resource Area 9. The eskers rise approximately 40 to 60 feet (12 to 18 m) above the surrounding terrain and are buried beneath glaciolacustrine fine-grained sediments. Subsurface information is presently lacking for these deposits, but as they are part of the same esker system forming Resource Area 8 in the Marathon Map Area, Area 9 is expected to contain similar materials and have a comparable resource potential as that described for Area 8.

Approximately 105 acres (42 ha) are presently available for extraction in Area 9. Assuming an average depth of 50 feet (15 m), resource tonnages are estimated to be 13 million tons (12 million tonnes). Although no extractive development has occurred in the resource area, Area 9 represents a valuable future source of sand and gravel. The deposits are considered to be within a reasonable trucking distance of the Hemlo camp and a logging road, which, during field investigation was under construction, should provide good access.

Selected Sand and Gravel Resource Area 10

Resource Area 10 consists of five esker ridges which are situated near the eastern boundary of the central part of the map area. Subsurface data are lacking for these deposits and the esker material appears to be overlain by a variable thickness of fine-grained glaciolacustrine sediments. Nevertheless, based on information on other esker deposits in the Hemlo Area, significant resources of quality aggregate may be available. Although these ridges have been classified as sand sources, areas of gravel concentration likely exist.

The esker ridges occupy 70 acres (28 ha) currently available for extraction. Assuming a deposit thickness of 30 feet (9 m), potential aggregate resources are estimated to total 5 million tons (5 million tonnes). The eskers are considered important future sources of aggregate and may be able to supply construction materials for logging road construction which was ongoing in the area during field investigation.

Selected Sand and Gravel Resource Area 11

Selected Sand and Gravel Resource Area 11 is located near Highway 614 in the central part of the map area. The deposit consists of a core of poorly sorted ice-contact material overlain by well stratified glaciolacustrine beach sediments. Although this deposit has been classified as a gravel source, areas of predominantly sandy aggregate exist. Two pits have been developed in the resource area. In pit no. 85, 4 feet (1.2 m) of fine gravel overlies 16 feet (5 m) of fine to medium sand. Faces in pit no. 81 revealed 15 feet (5 m) of sandy fine gravel. A sample taken from this pit contained 36 percent gravel, 62 percent sand and 2 percent fines (Figure 8a). The deposit appears well suited for extraction of pit-run aggregate for local road-building and general construction purposes.

Two seismic lines and a test hole have been placed in the deposit. The seismic lines indicate approximately 16 to 19 feet (5 to 6 m) of aggregate overlying bedrock in the areas tested. Test hole HE-TH-7 uncovered 8 feet (2 m) of fine to coarse sand with minor amounts of fine gravel (Figures 9a and 9b).

Resource Area 11 occupies 220 acres (89 ha), of which 200 acres (81 ha) are considered available for extraction. Assuming an average depth of 15 feet (5 m), sand and gravel resources are estimated to be 8 million tons (7 million tonnes). Access is provided by a logging road which branches off Highway 614 near Agonzon.

Selected Sand and Gravel Resource Area 12

An esker ridge and five ice-contact deposits located southwest of the community of Manitouwadge are included in Resource Area 12. The esker and surrounding ice-contact deposit located in close proximity to Manitouwadge have been designated as Area 12a. Pit no. 95 has been developed in Area 12a with faces exposing 40 to 60 feet (12 to 18 m) of medium to coarse gravel with abundant oversize clasts. A sample taken of this material consisted of 64 percent gravel, 35 percent sand and 1 percent fines (Figure 8a). During field investigation, aggregate from the pit was being extracted for use as 19 mm crushed stone and concrete aggregate in the construction of the Manitouwadge airport. A primary crusher was being used to enable the use of the abundant oversize material. Pit data on file at M.T.C. indicate that material from the pit has been used for granular base course and asphaltic aggregate. Similar quality aggregate to that exposed in pit no. 95 is probably available from the four ice-contact deposits which constitute Area 12b. Coarse gravel is abundant on the surfaces of these deposits and in pit no. 92 the gravel content has been estimated at 40 to 50 percent.

In general, the gravel in Area 12 appears to be of sufficient quality for most aggregate uses including pit-run products, G.B.C. A, and 16 mm crushed stone, but caution should be exercised in using the material for high quality, service demand concrete or hot-laid asphalt. This is because of the presence of chert in the deposit, which seems to be concentrated in the sand fraction of the aggregate, may have an undesirable effect on concrete and asphalt quality.

Resource Area 12 occupies 205 acres (83 ha). Cultural setbacks and previous extraction reduce the area currently available to 175 acres (71 ha). Assuming average thicknesses of 50 and 15 feet (15 and 5 m) for Areas 12a and 12b, respectively, aggregate resources total approximately 10 million tons (9 million tonnes). Access in Area 12a via Highway 614 is excellent and bush roads provide access to Area 12b.

Selected Sand and Gravel Resource Area 13

Selected Sand and Gravel Resource Area 13 includes three esker ridges along with an ice-contact and outwash deposit. The deposits are situated within a north-south trending bedrock depression west of the community of Manitouwadge. Two pits have been opened in the southern outwash deposit, designated as Area 13a. The pits are primarily sand sources although concentrations of fine gravel were observed in the northern face of pit no. 91. A sample taken from this face contained 37 percent gravel, 58 percent sand and 5 percent fines (Figure 8a). The sandy aggregate in pit no. 91 is generally suitable for pit-run purposes. Caution should be exercised if the material in the deposit is to be used for concrete or hot-laid products as the aggregate may contain undesirable amounts of chert. A chert content of 14.4 percent in the coarse fraction was determined in the sample taken during the field investigation (Appendix D). In the undeveloped part of Area 13a, north of Sand Lake, the aggregate may become coarser as the topography is more hummocky and the material is believed to have been deposited in closer proximity to the glacial ice. Access to the southern part of the deposit is provided by a bush road that branches off Caramat Road.

The ice-contact and esker ridges which form Areas 13b and 13c, respectively, are located north of Area 13a. Although subsurface data is lacking for these deposits, they contain potential sand and gravel resources which may be suitable for local use. The esker segments likely contain higher contents of gravel. Access to Areas 13b and 13c is presently limited.

Resource Area 13 occupies 255 acres (103 ha), of which 218 acres (88 ha) are considered available for extraction. Assuming average thicknesses ranging from 12 to 18 feet (4 to 6 m) for the deposits, total aggregate resources are approximately 10 million tons (9 million tonnes).

Selected Sand and Gravel Resource Area 14

Five esker segments (Area 14a) and an ice-contact deposit (Area 14b) located along the western boundary of Manitouwadge Township Municipality have been selected at the primary level of significance. No pits have been opened in the deposits and subsurface data are lacking. The resource area, however, is considered to contain significant potential resources of sand and gravel suitable for future extractive development. The esker ridges probably contain coarser aggregate than the surrounding ice-contact material. A shallow test pit excavated in one of these ridges revealed medium to coarse gravel which appears suitable for crushing. The northern part of the area lies in close proximity to Caramat Road which would enhance development.

Approximately 280 acres (113 ha) are currently available for extraction in Resource Area 14. Assuming average depths of 25 and 19 feet (8 and 6 m) for Areas 14a and 14b, respectively, total resource tonnages are estimated to be 13 million tons (12 million tonnes).

Sand and Gravel Resource Areas of Secondary Significance, Manitouwadge Map Area

Two ice-contact deposits and an outwash deposit, located southeast of Resource Area 9 along the southern border of the map area, have been selected at the secondary level. The deposits are generally suitable for local aggregate uses and access is provided by a bush road which joins Highway 614 near Amwri Creek and extends to the Black River. The easternmost ice-contact deposit consists of a variable thickness of poorly sorted sandy gravel over bedrock or till. The aggregate may be dirty in places and hummocks or ridges of this material appear better suited for extraction. Pit no. 68, opened in the western ice-contact deposit, exposed 10 feet (3 m) of aggregate with an estimated gravel content of 35 to 40 percent. Five to 10 feet (1.5 to 3 m) of coarse sand with some fine gravel was observed in pit no. 67 developed in the outwash deposit.

Two esker deposits, one located southwest of Resource Area 9 and the other west of the southern esker ridges of Resource Area 10, have also been selected at the secondary level. These eskers are expected to contain similar materials to those described for Areas 8, 9 and 10. The ridges, however, are not as prominent, possibly reflecting more intense glaciolacustrine reworking.

Considerable resources of sandy aggregate are considered available from the ice-contact deposits which flank, or are in the vicinity of, Resource Areas 9 and 10. Similar to the deposits surrounding Resource Area 8, most of these ice-contact features are considered to be overlain by a variable thickness of fine-grained glaciolacustrine sediments. The deposits exhibit a hummocky topography often pitted by kettle depressions.

Four ice-contact deposits, modified by lake action, lie along Highway 614 between Barehead Lake and Agonzon. Five pits have been opened in these deposits. The pits expose between 6 and 50 feet (1.8 and 15 m) of chiefly sandy aggregate generally suitable for lower specification uses such as G.B.C. C and fill. Limiting sand use factors include the presence of silt and clay seams in sections. An abundance of chert in the coarse sand and fine gravel fractions may restrict high specification use of the aggregate. The thickness of the aggregate in the southernmost deposit is considered variable and bedrock is exposed in the floors of pit nos. 83 and 84.

The remaining deposits selected at the secondary level in the map area lie within Manitouwadge Township Municipality. One such deposit flanks Resource Area 12b. The deposit consists of a variable thickness of ice-contact gravel over bedrock and was deposited in a similar geological environment as Resource Area 12. In addition, an ice-contact deposit is situated along the eastern boundary of the municipality. Three pits have been opened in this deposit exposing largely sandy aggregate suitable for local aggregate use.

Ice-contact deposits are also located near Resource Areas 13b and 13c. These deposits are considered to contain similar materials as Resource Area 13b, but extraction depth may be limited by a potentially high water table and variable depth to bedrock. Northeast of these deposits along Garnet Lake another ice-contact deposit is located. One pit has been opened in this deposit revealing material ranging from fine sand to coarse gravel suitable for local aggregate use. Along Rabbitskin Lake, near the northern boundary of the municipality, lies an ice-contact and esker deposit. Although access to these deposits is currently limited, they represent valuable future aggregate sources especially if activities such as logging or mining are undertaken in the vicinity. The esker ridge may contain higher concentrations of gravel than the surrounding ice-contact material. A potentially high water table may limit the depth of extraction in these deposits.

SELECTED SAND AND GRAVEL RESOURCE AREAS, WHITE RIVER MAP AREA (MAP 2C)

Selected Sand and Gravel Resource Area 15

Selected Sand and Gravel Resource Area 15 includes two esker segments and an associated ice-contact deposit located west of White Lake in the northwestern part of the White River Map Area. The combined length of the esker segments is approximately 2.7 km and the ridges have local relief of 15 to 50 feet (5 to 12 m). The depth to bedrock may be variable in the northernmost esker ridge. A hummocky topography with several deep kettle depressions typifies the ice-contact deposit. The resource area is presently inaccessible by road and no extractive operations have been opened.

During field investigation, two samples were taken along the flank of the southernmost esker ridge. Between 19 and 54 percent gravel was revealed in these samples (HE-SS-2 and HE-SS-3, Figure 16a). In the vicinity of sample site HE-SS-2, M.T.C. has also investigated the nature of the aggregate. In the 48-foot (15 m) exposure examined, crushable gravel is reported as occurring in pockets within a sandy mass. Potential uses of the aggregate include granular base course and 16 mm crushed stone. Higher concentrations of gravel may be encountered in the core of these ridges than along the flanks. The ice-contact deposit is expected to contain similar quality aggregate as the esker segments.

Approximately 205 acres (83 ha) are currently available for extraction in Resource Area 15. Assuming an average depth of 30 feet (9 m) for Area 15a and 15 feet (5 m) for Area 15b, sand and gravel resources are estimated to total 14 million tons (13 million tonnes).

Selected Sand and Gravel Resource Area 16

Resource Area 16 is situated in Laberge Township, mostly within Pic-Mobert North Indian Reserve. One pit has been developed in the deposit. Faces in pit no. 112 expose between 10 and 30 feet (3 and 9 m) of aggregate deposited in an outwash environment. Two excavations into the pit faces were undertaken by M.T.C. One of these excavations uncovered 15 feet (5 m) of medium to coarse gravel while 10 feet (3 m) of sand with minor fine gravel was revealed in the other. A sample taken from this source contained 38 percent gravel, 61 percent sand and 1 percent fines (Figure 10a). The most readily produced construction product from this pit is likely pit-run aggregate. The general fineness of the gravel and abundance of sand, in sections, would restrict the amount of crushable gravel available.

Resource Area 16 occupies 20 acres (8 ha) of which 13 acres (5 ha) are considered available for extraction. Assuming an average thickness of 20 feet (6 m), aggregate resources total approximately 1 million tons (1 million tonnes).

Selected Sand and Gravel Resource Area 17

An ice-contact deposit located along the southern boundary of Bryant Township has also been selected at the primary level. Three pits have been opened in the resource area with faces ranging between 5 and

20 feet (1.5 and 6 m) high. M.T.C. has tested the aggregate in pit no. 121 and reports that it is generally of good quality and suitable for use as granular base course, 16 mm Crushed Type A and H.L. 4 stone. In sections, sand control may be necessary for crushing and a primary crusher would be beneficial in utilizing oversize material. The sand fraction of the aggregate would require blending for asphaltic use and a lack of fines to ensure good compaction may be a problem for production of G.B.C. C. Bedrock has been encountered 5 feet (1.5 m) beneath the pit floor. A sample taken from the pit revealed a gravel content of 52 percent (Figure 11a).

Similar quality gravel was also observed in the undeveloped area north of pit no. 121. Samples taken from test hole HE-TH-10 and sample site HE-SS-5 contained 60 and 51 percent gravel, respectively (Figures 14a and 17a). In addition, several test holes placed by M.T.C. just north of the pit exposed up to 15 feet (5 m) of aggregate containing 50 to 70 percent gravel. Tests performed on the aggregate from these test holes indicate it is generally hard and durable. Data for a seismic line (HE-GT-26) placed near test hole HE-TH-10 indicate a minimum of 40 feet (12 m) of aggregate. South of pit no. 121 the aggregate becomes finer with estimated gravel contents ranging from 30 to 35 percent in pit nos. 119 and 120.

Resource Area 17 occupies 320 acres (130 ha). Cultural setbacks and previous extraction reduce the area currently available to 260 acres (105 ha). Assuming an average thickness of 25 feet (8 m), available sand and gravel resources are estimated to be 16 million tons (15 million tonnes). Area 17 is readily accessible via a gravel-surfaced road which branches off Highway 17.

Selected Sand and Gravel Resource Area 18

Resource Area 18 consists of two esker segments in northern Cecile Township. The segments form part of a lengthy esker system that extends northward through Flood Township (outside the map area). No subsurface data is presently available for the resource area and deposit boundaries have been delineated by airphoto interpretation. However, based on data for other esker deposits in the report area, significant resources of quality aggregate may be available. Resource Area 18 repesents a valuable future aggregate source, especially if activities such as logging are undertaken in the vicinity. The deposits are currently inaccessible by road.

Approximately 60 acres (24 ha) are available for extraction in Resource Area 18. Assuming an average deposit thickness of 25 feet (8 m), resource tonnages are estimated to total 4 million tons (4 million tonnes).

Selected Sand and Gravel Resource Area 19

Selected Sand and Gravel Resource Area 19 is located in southern Cecile Township. The deposit is a complex feature consisting of material deposited in an ice-contact environment. Several 30- to 60-foot (9 to 18 m), north-south oriented ridges traverse the area. A number of 3-to 6-foot (1 to 1.8 m) exposures were observed in these ridges along the hydro line which crosses the deposit. Close to the esker deposit of Resource Area 21, the aggregate revealed in the exposures consisted of medium to coarse gravel with a coarse sand matrix. Further away from the esker the sediment became finer and the gravel content decreased. In the southern part of the resource area, an exposure along Highway 17 revealed 8 to 15 feet (2 to 5 m) of sandy gravel with an estimated gravel content of 50 percent.

Based on existing data, Area 19 appears to have good potential for crushable gravel. In areas, however, the deposit consists dominantly of sand and fine gravel which more easily would satisfy lower specification construction uses. The deposit occupies 390 acres (158 ha) of which 350 acres (142 ha) are considered available for extraction. Assuming an average depth of 25 feet (8 m), aggregate resources are estimated to be 22 million tons (20 million tonnes). The area is accessible via Highway 17 and a hydro line service road.

Selected Sand and Gravel Resource Area 20

An outwash deposit situated east of North Crocker's Lake in southern Cecile Township has also been selected at the primary level of significance. One pit (pit no. 135) has been developed in the resource area. Five to eight feet (1.5 to 2 m) of sandy fine to medium gravel is exposed in the pit. A sample taken of this material revealed a gravel content of 41 percent (Figure 12a). In the floor of the pit a test hole was excavated and adjacent to the test hole a seismic line was run. Test hole HE-TH-16 uncovered 8 feet (2 m) of well stratified sandy gravel which was slightly coarser than that exposed in the pit faces (Figure 15a). Information obtained from seismic line HE-GT-39 indicates that approximately 7 feet (2 m) of sandy gravel overlies sand and gravel or a stony till. The aggregate in this deposit appears suited for the production of a variety of construction products. Sand control, however, would likely be required for crushing and a lack of fines to ensure good compaction may be a problem for production of G.B.C. C.

Resource Area 20 occupies approximately 40 acres (16 ha), of which 39 acres (16 ha) are currently available for extraction. Assuming an average deposit thickness of 15 feet (5 m), sand and gravel resources are considered to be 1 million tons (1 million tonnes). Access to the area is provided by a logging road which branches off Highway 17.

Selected Sand and Gravel Resource Area 21

Resource Area 21 consists of six esker segments that trend southward through Cecile and Knowles Townships. The esker ridges generally rise between 40 and 60 feet (12 and 18 m) above the surrounding terrain and are often flanked by kettle depressions.

Area 21a is the northernmost esker segment. One pit (pit no. 131) has been developed in Area 21a exposing up to 60 feet (18 m) of slumped coarse gravel with a coarse sand matrix. M.T.C. reports that the material extracted from the pit is suitable for use as G.B.C. A and C, and H.L. 4 stone. Abundant oversize clasts were observed in the pit and a primary crusher may be beneficial in utilizing this material. In sections, sand control would be required for crushing and a lack of fines to ensure good compaction may be a problem for production of G.B.C. C. The sand fraction of the aggregate would require blending for hot-laid use.

Gravel similar to that exposed in pit no. 131 was uncovered in several 11- to 15-foot (3 to 5 m) deep test holes excavated by M.T.C. just north of the pit. Samples from the test holes contained an average gravel content of approximately 60 percent and the gravel was generally hard and durable. Oversize material was often concentrated in the upper levels of these test holes. In addition, a test hole (HE-TH-15) and seismic line (HE-GT-38) were placed in the northern end of the deposit. Information obtained from these sources indicates that gravel of similar quality extends to the northern part of Area 21a. Access to the deposit is provided by Highway 17 and a hydro line service road.

One presently abandoned pit (pit no. 128) has been opened in the southern part of Area 21b. The slumped faces in this pit range from 30 to 40 feet (9 to 12 m) high. A sample taken from the pit revealed a gravel content of 55 percent (Figure 12a). In the northern part of the deposit a test hole (HE-TH-13) and seismic line (HE-GT-32) were placed. The test hole revealed 3 feet (1 m) of oversize material, over 6 feet (1.8 m) of clean, sandy fine to medium gravel. The sandy gravel was sampled and contained 40 percent gravel (Figure 15a). A minimum of 40 feet (12 m) of granular material is indicated by the seismic data. The gravel exposed in Area 21b is similar in quality and use suitability to that in Area 21a, although it is slightly finer. Therefore, sand control may have to be utilized to a greater extent while crushing. The deposit is accessible via a system of logging roads (which branch off Highway 17) and a line of the Canadian Pacific Railway.

Area 21c includes four esker ridges located south of Area 21b. The deposits are expected to contain aggregate of comparable quality to that described in Areas 21a and 21b as they are part of the same esker system. Access to the northern esker segments is currently limited, but a recently developed logging road system provides access to the two southernmost deposits. No extractive development has occurred in Area 21c, but the deposits are considered to be valuable future aggregate sources for the White River area.

Resource Area 21 totals 290 acres (117 ha). Cultural constraints and previous extraction reduce the area currently available to 280 acres (113 ha). Assuming an average thickness of 50 feet (15 m) for the esker segments, aggregate resources are estimated to be 34 million tons (31 million tonnes).

Selected Sand and Gravel Resource Area 22

Selected Sand and Gravel Resource Area 22 is located west of Area 21b, along the boundary of Cecile and Knowles Townships. The deposit is a relatively flat outwash plain although several hummocky features of ice-contact origin are also present. Two pits have been developed in the deposit. In pit no. 127, 10 to 30 feet (3 to 9 m) of uniformly stratified, sandy fine to coarse gravel was actively being extracted at the time of field investigation. The aggregate from the pit was utilized largely for the manufacture of a range of crusher-run products for use in the Hemlo mine developments. A sample taken from the pit contained 56 percent gravel and 44 percent sand (Figure 11a). Ten to twelve feet (3 to 4 m) of similar quality gravel was exposed at pit no. 129 in the northern end of the deposit.

One test hole and two seismic lines were placed in Area 22. Test hole HE-TH-12 uncovered 10 feet (3 m) of fine to coarse gravel. This material was sampled and contained 55 percent gravel, of which 51 percent was greater than 26.5 mm (Figure 14a). Data for seismic line HE-GT-31, placed on the floor of pit no. 129, indicate approximately 19 feet (6 m) of sandy gravel overlies bedrock. A minimum of 25 feet (8 m) of aggregate was revealed by seismic line HE-GT-28.

In summary, Resource Area 22 is considered well suited for extractive development and contains significant resources of hard and durable aggregate. Limiting aggregate use factors, if encountered, are likely to include excessive quantities of sand, necessitating sand control measures when crushing, and a lack of fines to ensure proper compaction for G.B.C. C. Excellent access is provided by a system of logging roads which branch off Highway 17.

Resource Area 22 occupies approximately 68 acres (28 ha), of which 66 acres (27 ha) are currently available for extraction. Assuming an average depth of 25 feet (8 m), sand and gravel resources are estimated to be 4 million tons (4 million tonnes).

Selected Sand and Gravel Resource Area 23

Five esker segments situated in White River Township Municipality are included in Resource Area 23. The northernmost esker ridge has been designated as Area 23a and has been a traditional source of aggregate in the municipality. Eight pits have been opened in the deposit with faces between 15 and 50 feet (5 and 15 m) high. The aggregate exposed in these pits is variable, ranging from fine sand with silt layers to pockets of coarse crushable gravel. The material is generally suitable for use as G.B.C. A and C, as well as H.L. 4 stone. In places, selection and sand control would probably be required for crushing because of excessive quantities of sand. Selection would also be necessary to avoid occasional silt layers and pockets of dirty granular material. The sand fraction of the aggregate grades from fine to coarse for hot-laid use. Consequently, blending would be required for this use. A sample taken from pit no. 142 contained 50 percent gravel which was of high quality (Figure 13a). Area 23a is readily accessible by Highway 17 and a bush road which links the pits to the highway.

Four esker ridges to the south of Area 23a have been labelled Area 23b on Map 2C. A number of exposures, up to 75 feet (23 m) high, have been cut into the ridges along a recently constructed logging road. In addition, a pit (pit no. 132) with 40-foot (12 m) high faces has been opened along the road. Both the exposures and pit faces reveal a predominance of sandy aggregate with interbedded gravel layers. Considerble amounts of lower specification aggregate are considered available from these deposits. In addition, gravel suitable for crushing exists in pockets within the sandy sediment.

Resource Area 23 totals 210 acres (85 ha). After previous extraction and cultural setbacks are considered, approximately 170 acres (69 ha) are currently available for extraction. Assuming average thicknesses of 30 feet (9 m) and 50 feet (15 m) for Areas 23a and 23b, respectively, presently available sand and gravel resources are estimated to be 19 million tons (17 million tonnes).

Sand and Gravel Resource Areas of Secondary Significance, White River Map Area

The ice-contact deposits associated with Resource Area 15 have been selected at the secondary level of significance. The deposits exhibit a hummocky topography and are considered predominantly sand sources. The sandy aggregate appears suitable for low-specification aggregate uses and has potential as a source of mine backfill. Further investigation, however, would be required to identify specific sites best suited for extractive development because of the inherent variability of ice-contact deposits and an irregular depth to bedrock in some areas.

An east-west trending ice-contact ridge is located south of Resource Area 16 in Laberge Township. Material exposed at the surface is largely sand and one pit has been opened in the deposit. Faces in pit no. 111 exposed between 5 and 10 feet (1.5 and 3 m) of sandy aggregate suitable for local construction uses.

Three deposits in McCron Township have also been selected at the secondary level. Sandy gravel is the dominant sediment exposed in the outwash deposit in the southwestern part of the township. Three pits have been opened in this deposit with faces ranging from 5 to 10 feet (1.5 to 3 m) high. A sample taken from one of these pits (pit no. 114) contained 59 percent gravel (Figure 10a). The aggregate appears suited for a variety of aggregate uses, especially for local road maintenance. Two small esker ridges located north of this outwash deposit are also potential aggregate sources.

Considerable aggregate resources have been selected at the secondary level in Cecile and Knowles Townships. Included are two ice-contact deposits which flank Resource Areas 21b and 22 in northern Knowles Township. The deposits exhibit hummocky relief and the material exposed at the surface is largely sand, although gravel is concentrated in localized areas. Local accumulations of sandy gravel were observed at pit no. 132 and in several hummocks located just east of the northern part of Resource Area 21b. Additional quantities of gravel may underlie sand in places within these deposits. A test hole excavated in the western deposit revealed 8 feet (2 m) of medium to coarse sand with minor amounts of fine gravel. Seismic data indicate the presence of a significant thickness of aggregate. A system of logging roads and a line of the Canadian Pacific Railway provide excellent access to the area.

Three outwash deposits are situated along the border of Cecile and Knowles Townships. One flanks Resource Area 22 and sand is the predominant surficial material. However, in places, the sand may overlie and mask coarser aggregate. The other two deposits are located near Dead Lake. Two pits have been developed in the northernmost of these deposits exposing 6 to 12 feet (1.8 to 4 m) of sandy fine gravel. This material appears best suited for pit-run uses as gravel in the crushable size range is lacking. Sand with fine gravel is exposed on the surface of the southernmost deposit and 8 feet (2 m) of this material was uncovered in test hole HE-TH-14.

Flanking Resource Area 19 in southern Cecile Township are three ice-contact deposits. The southernmost of these deposits is a hummocky feature containing numerous kettle depressions. The predominant sediment exposed at the surface is gravelly sand and in areas bedrock is close to the surface. The other two deposits are expected to contain material similar to that described for Resource Area 19. Along the hydro line which crosses these deposits, sandy fine gravel was observed on the surface of several ridges. These ridges tended to exhibit lower relief than those in Resource Area 19 and in parts of the deposits the water table may be close to the surface. Access to these areas is provided by a hydro line service road and a bush road east of North Crocker's Lake.

The remaining deposits selected at the secondary level in Cecile and Knowles Townships are located south of the White River and north of Resource Area 19. Access is poor in these areas, with the exception of southern Knowles Township, and little subsurface data is presently available. The majority of these deposits consist of ice-contact and outwash sediments and are associated with esker ridges which traverse the two townships. Five small esker segments in northern Cecile Township are also included. Although further investigation is required to identify specific sites well suited for extractive development in these deposits, they are considered to contain significant potential resources of sand and gravel. Most of these deposits have been classified as sand sources, but areas of gravel concentration are expected to exist.

The final deposits selected at the secondary level are located within White River Township Municipality. Three pits have been developed in an ice-contact deposit east of Picnic Lake. Between 5 and 15 feet (1.5 and 5 m) of poorly sorted fine to coarse gravel is exposed in these pits. The aggregate extracted from these pits is generally suitable for uses including granular base course and H.L. 4 stone. Only limited quantities of aggregate remain in the deposit, however, because of previous extraction. A small esker ridge situated just northeast of this deposit is expected to contain aggregate of comparable quality. Aggregate suitable for local construction uses is also available from several small esker ridges and an associated ice-contact deposit in the southeastern corner of the township. Faces in pit no. 153, developed in one of these esker ridges, exposed 10 to 20 feet (3 to 6 m) of irregularly bedded gravelly sand.

BEDROCK GEOLOGY AND RESOURCE POTENTIAL

For the most part, the bedrock in the project area is Early Precambrian (Archean) in age. The exceptions are the intrusive Port Coldwell Alkalic Complex, near Marathon, of Late Precambrian age and possibly the diabase dikes of undetermined age. The bedrock is part of the Superior Province of the Canadian Shield. Geological mapping by Thomson (1931), Pye (1957), Milne (1967; 1968; 1974), Coates (1968), Bennett et al. (1969), Muir (1982a; 1982b) and Siragusa (1984a; 1984b; 1985a; 1985b) covers most of the report area. The regional geology of the area is portrayed in Figure 2.

The dominant rock type within the study area is granitic rock, of which granodiorite is the most common variety. Two major belts consisting of metasedimentary and metavolcanic bedrock are also present in the area. One belt extends from east of White Lake to Heron Bay and includes the site of the major gold discovery at Hemlo. Intensive mineral exploration is currently ongoing in this belt. The other belt is located at Manitouwadge and has been the site of significant copper-zinc-silver mining. Also included within the project area is the Port Coldwell Alkalic Complex near Marathon and small bodies of mafic and ultramafic rocks. Numerous diabase dikes traverse the report area.

Of the bedrock in the report area, the granitic rocks are considered the most suitable for potential crushed stone production. One quarry, with faces ranging from 5 to 20 feet (1.5 to 6 m) high, has recently been established in this rock type near the Hemlo mining camp. The rock extracted from the quarry has been used in mine construction, including use in concrete, at the Hemlo camp. Although no quality limitations have been reported on the use of crushed stone from this quarry, detailed testing should be undertaken to ensure that the stone is suitable for use in high service demand concrete. Rogers (1983) reports that granitic rock can possibly react with portland cement concrete resulting in concrete deterioration over the years. There should be no limitations on the use of this stone for all other usual applications.

Other potential sources of bedrock-derived aggregate include the mafic igneous rocks. One variety, quartz-bearing diabase, is usually hard and massive, and has been found suitable for quarry development elsewhere in Ontario. Factors such as the width and purity of the diabase dikes, along with the abrasive nature of these rocks on crushing equipment, would influence quarry development. In addition, waste rock from the mines may have potential as a source of some aggregate products. Extraction of bedrock in the study area has also taken place in a number of long-abandoned quarries near Marathon (Hewitt 1964). The black and red granites quarried from these sites between 1928 and 1932 were used as building stone.

Within the report area, considerable latitude exists in choosing sites for potential bedrock extraction as there exists extensive areas where the bedrock is exposed at the surface or is covered by thin drift. Areas in which excessive overburden thicknesses would restrict bedrock extraction are generally located in valleys within the report area, such as the Black River valley.

Presently, the Aggregate Assessment Office would emphasize that, for any site proposed for quarry development, the site should be tested in detail before extraction occurs. The Precambrian rocks may vary in quality over relatively short distances and may be chemically reactive with concrete mixes.

SUMMARY

The sand and gravel deposits in the report area are the product of glacial activity which occurred during the Late Wisconsinan. Several of these deposits containing significant resources of sand and gravel have been grouped together into twenty-three Primary Resource Areas. In addition, numerous deposits of secondary significance have been selected which considerably add to the project area's resource base. Care should be taken to ensure the continued availability of as much of the resource areas as possible.

The aggregate in the report area is generally hard and durable and suitable for most aggregate applications. Use of the material for high service demand concrete and hot-laid asphalt, however, may be limited in places by the presence of chert. The chert tends to be concentrated in the medium sand to fine gravel component of the aggregate and increases in content towards the north in the vicinity of Manitouwadge.

Despite the perceived lack of aggregate in the early stages of development of the Hemlo mining camp, the sand and gravel deposits selected for possible resource protection, together with a quarry developed near the camp, appear adequate to meet most mine construction demands. Considerable resources have been selected within the municipalities of Marathon, Manitouwadge and White River where the demand for aggregate is also considered high. In more remote areas or in areas experiencing a lower demand for aggregate within the report area, the selected deposits represent valuable future sources of aggregate.

The study area is underlain predominantly by granitic, metasedimentary and metavolcanic rocks of Precambrian age. The granitic rocks are generally considered the most suitable of these rock types for the production of construction aggregates.

Enquiries regarding the Aggregate Resources Inventory of the Hemlo Area should be directed to the Ontario Ministry of Natural Resources at: the Wawa District Office, P.O. Box 1160, 22 Mission Road, Wawa, Ontario, P0S 1K0 (Tel. (705) 856-2396) or the Northeastern Region Office, 199 Larch Street, Sudbury, Ontario, P3E 5P9 (Tel. (705) 675-4128); the Terrace Bay District Office, P.O. Box 280, Terrace Bay, Ontario, P0T 2W0 (Tel. (807) 825-3205) or the North Central Region Office, P.O. Box 5000, Ontario Government Building, 435 James Street South, Thunder Bay, Ontario, P7C 5G6 (Tel. (807) 475-1331).

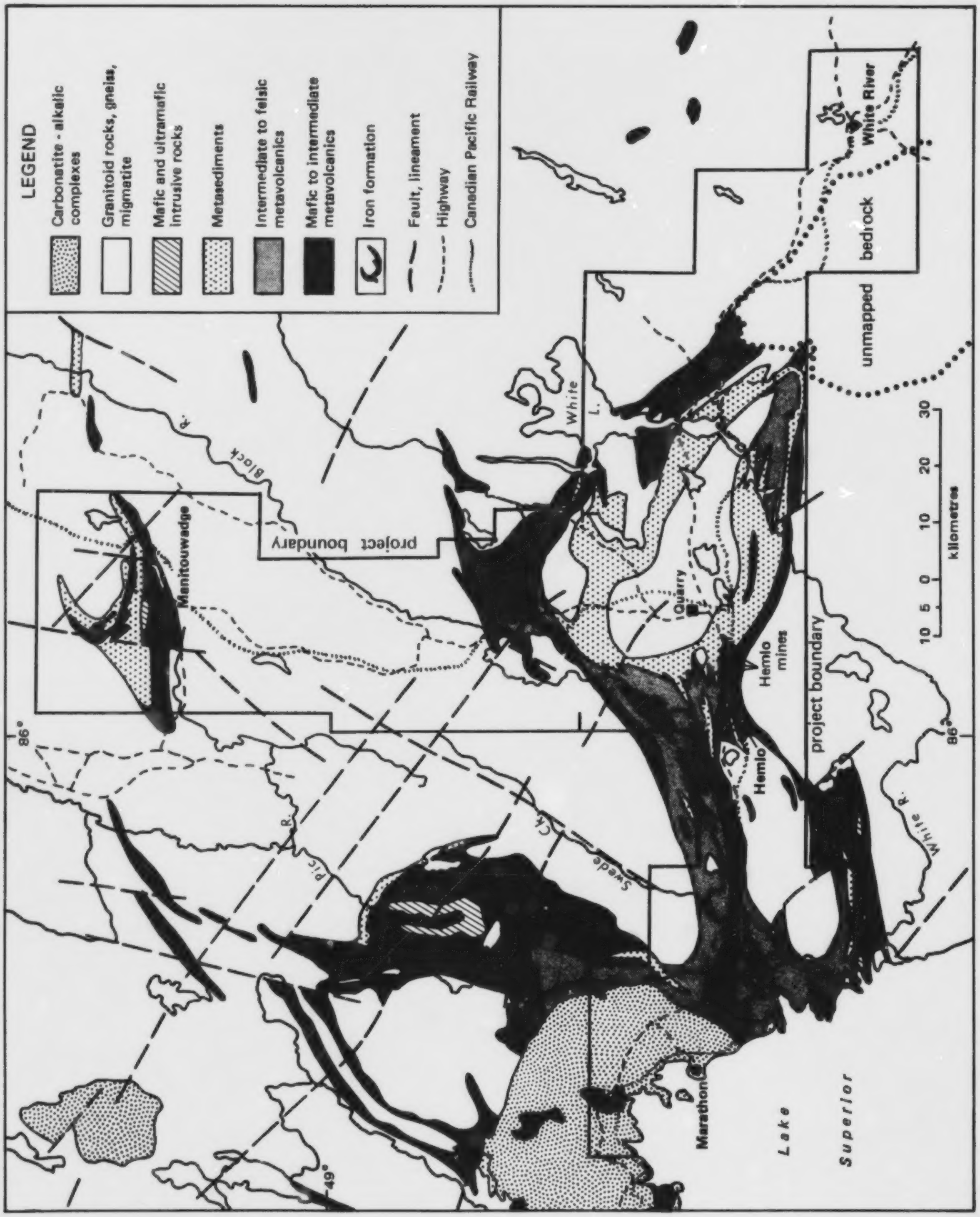


FIGURE 2: BEDROCK GEOLOGY OF THE HEMLO AREA

Modified after Muir (1982a, b), Ontario Department of Mines (1972) and Siragusa (1984a, 1984b, 1985a, 1985b).

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, HEMLO AREA*.

1 Class No.	2 Deposit Type (see Appendix C)	3 Areal Extent Acres (Hectares)	4 Original Tonnage Millions of Tons (Tonnes)
MARATHON MAP AREA			
Marathon Township Municipality			
1	G-IC	30 (12)	2 (2)
	G-LD	1420 (580)	142 (129)
	S-LB	1680 (680)	124 (112)
	S-LD	2160 (870)	212 (192)
2	G-IC	310 (125)	14 (13)
	G-LB	300 (121)	11 (10)
	S-IC	55 (22)	2 (2)
	S-LB	1270 (510)	48 (44)
	S-LB-LP-WD	430 (174)	16 (15)
	S-LD	550 (222)	22 (20)
	S-LP	8400 (3400)	315 (285)
	S-WD	900 (365)	27 (24)
3	G-IC	50 (20)	1 (1)
	S-LB	50 (20)	1 (1)
	S-LP	230 (93)	5 (5)
4	S-LP	70 (28)	1 (1)
		17,900 (7200)	940 (850)
Pic Township			
1	G-IC	50 (20)	3 (3)
	S-WD	25 (10)	2 (2)
2	G-IC-LB	15 (6)	1 (1)
	S-LB	30 (12)	1 (1)
	S-LD	2100 (850)	63 (57)
	S-LP	12,900 (5200)	485 (440)
	S-WD	45 (18)	2 (2)
3	G-IC-LB	20 (8)	<1 (<1)
	S-IC-LB	2 (1)	<1 (<1)
	S-LP	470 (190)	9 (8)
		15,700 (6400)	565 (510)
Lecours Township			
2	S-LP	12,600 (5100)	470 (425)
3	G-IC-LB	7 (3)	<1 (<1)
		12,600 (5100)	470 (425)
Bomby Township			
1	G-E	18 (7)	2 (2)
	S-IC	120 (49)	8 (7)
	S-OW	530 (214)	26 (24)

N.B. Minor variations in all tables are caused by rounding of data.

*Identified deposit areas within White Lake Provincial Park are omitted on all tables.

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, HEMLO AREA.

1 Class No.	2 Deposit Type (see Appendix C)	3 Areal Extent Acres (Hectares)	4 Original Tonnage Millions of Tons (Tonnes)
2	S-LP	4 (2)	<1 (<1)
3	G-IC	165 (67)	3 (3)
	S-IC	42 (17)	1 (1)
	S-LP	630 (255)	13 (12)
4	S-IC	165 (67)	2 (2)
	S-LP	200 (81)	2 (2)
	S-OW	145 (59)	1 (1)
		2020 (820)	58 (53)
Brothers Township			
2	S-IC	70 (28)	3 (3)
	S-LP	95 (38)	4 (4)
	S-OW	8 (3)	<1 (<1)
3	S-IC	240 (97)	5 (5)
	S-LP	285 (115)	6 (5)
	S-OW	940 (380)	19 (17)
4	S-IC	65 (26)	1 (1)
		1700 (690)	38 (34)
Unsurveyed			
1	G-E	37 (15)	3 (3)
	S-E	46 (19)	6 (5)
2	G-E	8 (3)	<1 (<1)
	S-IC	770 (310)	33 (30)
	S-LP	11,400 (4600)	430 (390)
	S-OW	150 (61)	6 (5)
3	G-E	1 (0.4)	<1 (<1)
	G-IC	105 (42)	2 (2)
	S-IC	265 (107)	5 (5)
	S-LP	1530 (620)	31 (28)
	S-OW	640 (260)	13 (12)
4	G-IC	1 (0.4)	<1 (<1)
	S-OW	105 (42)	1 (1)
		15,100 (6100)	530 (480)
Total for Marathon Map Area:		65,000 (26 500)	2600 (2360)
MANITOUWADGE MAP AREA			
Unsurveyed			
1	S-E	175 (71)	18 (16)
2	G-LB-IC	220 (89)	8 (7)
	S-E	75 (30)	3 (3)
	S-IC	1120 (455)	50 (45)
	S-LB-IC	430 (174)	16 (15)
	S-LP	21,900 (8900)	820 (740)
	S-WD-LP	730 (295)	27 (24)

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, HEMLO AREA.

1 Class No.	2 Deposit Type (see Appendix C)	3 Areal Extent Acres (Hectares)	4 Original Tonnage Millions of Tons (Tonnes)
3	G-IC	190 (77)	4 (4)
	S-E	55 (22)	1 (1)
	S-IC	550 (223)	11 (10)
	S-LP	40 (16)	1 (1)
	S-OW	235 (95)	5 (5)
4	S-LB	70 (28)	1 (1)
	S-OW	90 (36)	1 (1)
		26,000 (10 500)	970 (880)
Manitouwadge Township Municipality			
1	G-E	61 (25)	5 (5)
	G-IC	57 (23)	7 (6)
	S-IC	45 (18)	3 (3)
2	G-E	37 (15)	1 (1)
	G-IC	225 (91)	8 (7)
	S-IC	550 (223)	23 (21)
	S-LP	850 (345)	32 (29)
	S-OW	210 (85)	9 (8)
3	G-IC	270 (109)	6 (5)
	S-IC	330 (134)	7 (6)
	S-LB	16 (6)	<1 (<1)
	S-LP	3100 (1250)	62 (56)
	S-LP-WD	1220 (495)	27 (24)
4	G-IC	35 (14)	<1 (<1)
		7000 (2850)	190 (172)
Total for Manitouwadge Map Area:			
		33,000 (13 400)	1160 (1050)
WHITE RIVER MAP AREA			
Unsurveyed			
1	G-E	36 (15)	3 (3)
	G-IC	135 (55)	10 (9)
	S-OW	115 (47)	6 (5)
2	G-E	45 (18)	2 (2)
	S-IC	700 (285)	26 (24)
	S-OW	130 (53)	5 (5)
3	S-IC	160 (65)	3 (3)
	S-LP	580 (235)	12 (11)
	S-LP-WD	750 (305)	15 (14)
	S-OW	365 (148)	7 (6)
		3000 (1210)	89 (81)
Laberge Township			
1	G-OW	20 (8)	1 (1)
2	S-IC	270 (109)	10 (9)
	S-OW	1390 (560)	52 (47)

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, HEMLO AREA.

1 Class No.	2 Deposit Type (see Appendix C)	3 Areal Extent Acres (Hectares)	4 Original Tonnage Millions of Tons (Tonnes)
3	S-IC	42 (17)	1 (1)
	S-OW	1340 (540)	27 (24)
4	S-IC	420 (170)	4 (4)
		3500 (1420)	95 (86)
Bryant Township			
1	G-IC	325 (132)	20 (18)
2	S-OW	2500 (1010)	94 (85)
3	S-IC	700 (285)	14 (13)
	S-LP	75 (30)	1 (1)
	S-LP-WD	3000 (1210)	60 (54)
	S-OW	510 (206)	10 (9)
4	S-LP-WD	220 (89)	2 (2)
	S-OW	4 (2)	<1 (<1)
		7300 (2950)	201 (182)
McCron Township			
1	G-IC	2 (1)	<1 (<1)
2	G-OW	55 (22)	2 (2)
	S-E	50 (20)	2 (2)
	S-IC	190 (77)	5 (5)
	S-OW	5600 (2270)	210 (191)
3	S-IC	1120 (455)	22 (20)
	S-OW	870 (350)	17 (15)
4	S-OW	240 (97)	2 (2)
		8100 (3300)	260 (236)
Cecile Township			
1	G-E	140 (57)	13 (12)
	G-IC	390 (158)	24 (22)
	G-OW	40 (16)	2 (2)
	S-IC	30 (12)	2 (2)
	S-OW	44 (18)	3 (3)
2	G-E	17 (7)	1 (1)
	G-IC	370 (150)	14 (13)
	G-OW	40 (16)	1 (1)
	S-IC	485 (196)	22 (20)
	S-IC-OW	780 (315)	29 (26)
	S-OW	920 (370)	34 (31)
3	G-OW	35 (14)	1 (1)
	S-OW	160 (65)	3 (3)
	S-OW-IC	90 (36)	2 (2)
		3550 (1440)	151 (137)

TABLE 1. TOTAL SAND AND GRAVEL RESOURCES, HEMLO AREA.

1 Class No.	2 Deposit Type (see Appendix C)	3 Areal Extent Acres (Hectares)	4 Original Tonnage Millions of Tons (Tonnes)
Knowles Township			
1	G-E	210 (85)	26 (24)
	G-OW	77 (31)	5 (5)
	S-IC	860 (350)	64 (58)
	S-IC-OW	1550 (630)	81 (73)
	S-OW	135 (55)	7 (6)
	S-OW-IC	105 (42)	6 (5)
2	S-IC-OW	530 (214)	20 (18)
	S-OW	1350 (550)	51 (46)
3	S-LP	1230 (500)	25 (23)
	S-OW	100 (40)	2 (2)
	S-OW-IC	410 (166)	8 (7)
4	S-OW	20 (8)	<1 (<1)
	S-OW-IC	60 (24)	1 (1)
		6600 (2650)	295 (270)
White River Township Municipality			
1	G-E	90 (36)	7 (6)
	S-E	120 (49)	15 (14)
	S-IC	14 (6)	1 (1)
	G-IC	2 (1)	<1 (<1)
2	G-E	5 (2)	<1 (<1)
	G-IC	60 (24)	2 (2)
	S-E	15 (6)	<1 (<1)
3	G-IC	20 (8)	<1 (<1)
	S-IC	40 (16)	1 (1)
	S-LP	2200 (890)	44 (40)
4	S-E	8 (3)	<1 (<1)
		2550 (1030)	70 (64)
Total for White River Map Area:		34,500 (14 000)	1160 (1050)
TOTAL FOR STUDY AREA:		132,000 (53 000)	4900 (4450)

TABLE 2. SAND AND GRAVEL PITS, HEMLO AREA.

1 No.	2 MTC No.	3 Township	4 Face Height Feet (Metres)	5 % Gravel	6 Remarks
Marathon Map Area					
1	G22-3	Marathon Twp. Municipality	10-30 (3-9)	variable	partially overgrown
2	-	"	5-8 (1.5-2)	-	overgrown
3	-	"	15-20 (5-6)	sand	partially overgrown
4	-	"	20-40 (6-12)	sand	partially overgrown, dune sand
5	-	"	10-15 (3-5)	10-50	gravel pockets
6	-	"	10-20 (3-6)	50	
7	G22-4	"	10-20 (3-6)	5-15	recent extraction
8	G22-1	"	25 (8)	0-75	gravel located in pockets in pit floor
9	-	"	10-25 (3-8)	50-70	recently opened, oversize clasts abundant
10	-	"	15 (5)	50-70	recently opened
11	G22-5	"	25 (8)	40-70	recent extraction
12	M12-3	"	20 (6)	50-65	recent extraction
13	M12-2	"	10-15 (3-5)	10-30	recent extraction, bedrock outcrop in eastern face
14	-	"	20-30 (6-9)	30-40	
15	-	"	5 (1.5)	mainly sand	overgrown
16	-	"	5 (1.5)	mainly sand	overgrown
17	-	"	10-20 (3-6)	sand	overgrown, dune sand
18	-	"	15 (5)	40-60	presently a dump site
19	M12-4	"	10-15 (3-5)	40-60	partially overgrown
20	-	"	4 (1.2)	60-70	small borrow pit
21	-	"	-	-	dune sand overlying beach gravel
22	-	"	5 (1.5)	mainly sand	

TABLE 2. SAND AND GRAVEL PITS, HEMLO AREA.

1 No.	2 MTC No.	3 Township	4 Face Height Feet (Metres)	5 % Gravel	6 Remarks
23	-	"	4 (1.2)	25-40	small borrow pit
24	-	"	150-200 (46-61)	-	slumped faces
25	M12-5	"	15-25 (5-8)	40-60	
26	M12-1	"	10-20 (3-6)	sand	high fines content
27	M12-6	Pic Township	20-30 (6-9)	40-60	recent extraction
28	-	"	20-30 (6-9)	-	overgrown
29	-	"	4 (1.2)	sand	small borrow pit
30	M12-17	"	10 (3)	sand	high water table in area
31	-	"	10-15 (3-5)	sand	dune sand
32	M12-7	"	10-40 (3-12)	sand	slumped faces
33	M12-12	"	30-40 (9-12)	20-30	bedrock exposed in pit face, depleted
34	-	"	3-8 (1-2)	sand	overgrown
35	M12-8	"	5-8 (1.5-2)	sand	overgrown
36	-	"	5-8 (1.5-2)	sand	overgrown
37	-	"	20-40 (6-12)	30-50	bedrock exposed in pit face, near depletion
38	-	"	5-8 (1.5-2)	sand	overgrown
39	M12-10	"	25-30 (8-9)	60-70	bedrock exposed in pit face, near depletion
40	M12-10	Lecours Twp.	10-30 (3-9)	65-80	near depletion
41	M12-13	"	100 (30)	sand overlying varved silt and clay	pit enlarged through erosion by groundwater
42	-	Bomby Twp.	20 (6)	mainly sand	
43	C35-4	"	20 (6)	0-15	silt seams

TABLE 2. SAND AND GRAVEL PITS, HEMLO AREA.

1 No.	2 MTC No.	3 Township	4 Face Height Feet (Metres)	5 % Gravel	6 Remarks
44	C35-4	"	25 (8)	0-15	gravel pockets and bedrock exposed in pit floor
45	C35-11	"	5-30 (1.5-9)	20-40	recent extraction, bedrock exposed in pit
46	-	Unsurveyed	6 (1.8)	till	overgrown
47	-	"	10-20 (3-6)	till	bedrock exposed in pit floor
48	-	"	near depletion, tailings dam presently being constructed in area of the deposit		
49	-	"	10-25 (3-8)	40-70	recent extraction, pockets of dirty granular materials
50	-	"	15 (5)	50-70	recent extraction
51	-	"	20-25 (6-8)	50-70	recent extraction
52	-	"	10-20 (3-6)	0-30	recent extraction
53	C35-1	"	10-15 (3-5)	variable	near depletion, mixture of till, sand and gravel
54	-	"	15 (5)	till	high fines content
55	-	"	3-8 (1-2)	mainly sand	depleted, high water table
56	-	"	10 (3)	till	abundant oversize clasts, high fines content
57	-	"	5-18 (1.5-6)	10-40	recent extraction
58	-	"	5 (1.5)	mixture sand, gravel and till	
59	W16-1	"	5 (1.5)	35	
60	W16-1	"	10 (3)	30-50	esker segment near depletion
61	W16-3	"	10-20 (3-6)	0-10	
62	-	"	5-10 (1.5-3)	variable	inactive
63	W16-14	"	6-12 (1.8-4)	variable	
64	-	"	20 (6)	till	

TABLE 2. SAND AND GRAVEL PITS, HEMLO AREA.

1 No.	2 MTC No.	3 Township	4 Face Height Feet (Metres)	5 % Gravel	6 Remarks
65	-	"	80-90 (24-27)	gravelly sand	
66	-	"	50-65 (15-20)	25-35	recent extraction, gravel pockets
Manitouwadge Map Area					
67	-	Unsurveyed	5-10 (1.5-3)	15	
68	-	"	5-10 (1.5-3)	35-40	
69	-	"	-	-	faces have been graded, bedrock exposed on pit floor
70	W16-13	"	6 (1.8)	mainly sand	gravel pockets present, near depletion
71	-	"	3 (1)	mainly sand	faces have been graded
72	-	"	6 (1.8)	mainly sand	inactive
73	-	"	15-20 (5-6)	till	inactive
74	-	"	6 (1.8)	20-30	
75	W16-12	"	10-15 (3-5)	30-60	
76	-	"	5 (1.5)	35	inactive
77	-	"	10-30 (3-9)	-	depleted
78	-	"	12 (4)	silty fine sand, overlain by 2.5 feet (0.8 m) of varved silt and clay	
79	-	"	6 (1.8)	sand	inactive
80	-	"		sand	inactive
81	-	"	15 (5)	30-40	recent extraction
82	-	"	12 (4)	0-20	inactive, silt and clay seams
83	W16-4	"	10-30 (3-9)	15-30	inactive, bedrock exposed on pit floor
84	W16-9	"	6-12 (1.8-4)	15-30	inactive, bedrock exposed on pit floor
85	-	"	20 (6)	4 feet (1.2 m) of gravel over sand	

TABLE 2. SAND AND GRAVEL PITS, HEMLO AREA.

1 No.	2 MTC No.	3 Township	4 Face Height Feet (Metres)	5 % Gravel	6 Remarks
86	W16-8	"	50 (15)	mainly sand with gravel layers, inactive	
87	M33-4	"	10-25 (3-8)	10-20	recent extraction
88	-	"	10-30 (3-9)	10-40	near depletion
89	-	Manitouwadge Twp. Municipality	10-15 (3-5)	5	recent extraction
90	-	"	10 (3)	sand	silty sections
91	M33-5	"	10 (3)	0-40	fine gravel concentrated in northern face
92	-	"	10-15 (3-5)	40-50	
93	-	"	-	-	depleted
94	M33-3	"	-	-	depleted, presently a dump site
95	M33-1	"	40-60 (12-18)	50-70	recent extraction
96	-	"	5-20 (1.5-6)	variable	material ranges from sand with clay seams to coarse gravel
97	-	"	15 (5)	till	
98	-	"	5-20 (1.5-6)	mainly sand, near depletion	
99	-	"	20 (6)	-	depleted, slumped faces
100	-	"	-	-	rehabilitated
101	-	"	15 (5)	-	depleted
102	-	"	10 (3)	mainly sand	
103	-	"	30 (9)	mainly sand	
104	-	"	10 (3)	mainly sand	
105	-	"	15-20 (5-6)	dune sand	

TABLE 2. SAND AND GRAVEL PITS, HEMLO AREA.

1 No.	2 MTC No.	3 Township	4 Face Height Feet (Metres)	5 % Gravel	6 Remarks
White River Map Area					
106	-	Unsurveyed	5-10 (1.5-3)	sand	20- to 50-foot (6 to 15 m) quarried bedrock face present along western part of pit
107	C35-9	"	20 (6)	10	inactive
108	C35-9	"	10-15 (3-5)	sand	presently a dump site
109	C35-9	"	10-15 (3-5)	sand	inactive
110	-	Laberge	5 (1.5)	sand	within Indian Reserve, overgrown
111	-	"	5-10 (1.5-3)	25	partially overgrown
112	C35-10	"	10-30 (3-9)	30-40	mostly within Indian Reserve
113	-	McCron	5-10 (1.5-3)	40-60	partially overgrown
114	-	"	5-10 (1.5-3)	40-60	partially overgrown
115	-	"	10 (3)	30-40	partially overgrown
116	C35-8	"	10-15 (3-5)	10-20	inactive
117	-	"	10 (3)	20	largely depleted
118	-	Bryant	10-20 (3-6)	30-40	partially overgrown, largely depleted
119	-	"	5-20 (1.5-6)	30	partially overgrown, largely depleted
120	-	"	8 (2)	30-35	partially overgrown
121	C35-6	"	20 (6)	50-75	faces graded, bedrock beneath pit floor
122	KL20-1	"	5-10 (1.5-3)	20	
123	-	McCron		fine sand over bedrock	
124	-	"	15 (5)	sand	inactive
125	W36-28	"	3-10 (1-3)	sand	small borrow pit
126	W36-29	"	5 (1.5)	sand	partially overgrown

TABLE 2. SAND AND GRAVEL PITS, HEMLO AREA.

1 No.	2 MTC No.	3 Township	4 Face Height Feet (Metres)	5 % Gravel	6 Remarks
127	-	Knowles	10-30 (3-9)	40-60	recent extraction
128	-	"	30-40 (9-12)	40-55	slumped, overgrown
129	W36-34	Cecile	10-12 (3-4)	40-60	inactive
130	-	"	5-6 (1.5-1.8)	40-60	bedrock exposed in pit, largely depleted
131	W36-9	"	30-60 (9-18)	40-70	slumped
132	-	Knowles	10-15 (3-5)	30-40	inactive
133	-	"	6 (1.8)	30-35	small borrow pit
134	-	Cecile	12 (4)	30-50	inactive
135	-	"	5-8 (1.5-2)	35-60	inactive
136	W36-30	"	5-15 (1.5-5)	sand	inactive
137	-	"	3-5 (1-1.5)	sand	partially overgrown
138	-	White River Twp. Municipality	40 (12)	sand with pockets of crushable gravel	
139	-	"	20-25 (6-8)	40-50	recent extraction, gravel in pockets
140	-	"	25 (8)	40-50	recent extraction, gravel in pockets
141	-	"	20-25 (6-8)	20	recent extraction, gravel in pockets
142	W36-16	"	35 (11)	30-50	recent extraction, gravel in pockets
143	-	"	-	-	slumped, overgrown
144	W36-14	"	-	-	rehabilitated
145	W36-27	"	15-25 (5-8)	40-60	
146	W36-24	"	40-50 (12-15)	40-65	
147	-	"	5-15 (1.5-5)	-	depleted, overgrown
148	W36-22	"	5-15 (1.5-5)	60-90	near depletion
149	-	"	5-12 (1.5-4)	30-60	near depletion
150	W36-7	"	5-10 (1.5-3)	30-60	near depletion

TABLE 2. SAND AND GRAVEL PITS, HEMLO AREA.

1 No.	2 MTC No.	3 Township	4 Face Height Feet (Metres)	5 % Gravel	6 Remarks
151	-	*	5-10 (1.5-3)	till	
152	-	*	5 (1.5)	sand	near depletion
153	-	*	10-20 (3-6)	30	bedrock exposed in pit floor, crushable gravel in sections
154	-	*	5-15 (1.5-5)	30	depleted

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, HEMLO AREA*.

1 Deposit No.	2 Area Acres (Hectares)	3 Cultural Setbacks Acres (Hectares)	4 Extracted Area Acres (Hectares)	5 Available Area Acres (Hectares)	6 Estimated Deposit Thickness Feet (Metres)	7 Available Aggregate Millions of Tons (Tonnes)
MARATHON MAP AREA						
Marathon Township Municipality						
1a	425 (172)	50 (20)	5 (2)	370 (150)	40 (12)	37 (34)
1b	150 (61)	10 (4)	10 (4)	130 (53)	40 (12)	13 (12)
1c	850 (345)	0 (0)	0 (0)	850 (345)	40 (12)	85 (77)
1d	475 (192)	200 (81)	5 (2)	270 (109)	40 (12)	27 (24)
1e	85 (34)	25 (10)	5 (2)	55 (22)	20 (6)	3 (3)
1f	1600 (650)	265 (107)	15 (6)	1320 (530)	40 (12)	132 (120)
1g	220 (89)	0 (0)	0 (0)	220 (89)	19 (6)	10 (9)
	3800 (1540)	550 (223)	40 (16)	3200 (1300)		305 (275)
2a	75 (30)	10 (4)	0 (0)	65 (26)	19 (6)	3 (3)
2b	210 (85)	50 (20)	0 (0)	160 (65)	19 (6)	8 (7)
	285 (115)	60 (24)	0 (0)	225 (91)		11 (10)
3a	65 (26)	8 (3)	2 (1)	55 (22)	20 (6)	3 (3)
3b	1610 (650)	145 (59)	15 (6)	1450 (590)	30 (9)	109 (99)
	1680 (680)	153 (62)	17 (7)	1500 (610)		112 (102)
4	300 (121)	50 (20)	25 (10)	225 (91)	15 (5)	8 (7)
	6100 (2470)	810 (330)	82 (33)	5200 (2100)		435 (395)
Pic Township						
3b	5 (2)	0 (0)	0 (0)	5 (2)	30 (9)	<1 (<1)

*Values for cultural setbacks and extracted area were estimated at the time of field investigation. Because of rapid developments in the area, especially near the Hemlo camp, the reserve estimates may not reflect present conditions.

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, HEMLO AREA.

1 Deposit No.	2 Area Acres (Hectares)	3 Cultural Setbacks Acres (Hectares)	4 Extracted Area Acres (Hectares)	5 Available Area Acres (Hectares)	6 Estimated Deposit Thickness Feet (Metres)	7 Available Aggregate Millions of Tons (Tonnes)
Bomby Township						
5a	120 (49)	0 (0)	15 (6)	105 (42)	25 (8)	7 (6)
5b	18 (7)	0 (0)	0 (0)	18 (7)	35 (11)	2 (2)
5c	530 (214)	30 (12)	0 (0)	500 (202)	35 (11)	44 (40)
	670 (270)	30 (12)	15 (6)	620 (250)		53 (48)
Unsurveyed						
6a	26 (11)	0 (0)	10 (4)	16 (6)	30 (9)	1 (1)
6b	100 (40)	0 (0)	10 (4)	90 (36)	15 (5)	3 (3)
	126 (51)	0 (0)	20 (8)	106 (43)		4 (4)
7a	11 (4)	0 (0)	0 (0)	11 (4)	25 (8)	1 (1)
7b	26 (11)	0 (0)	0 (0)	26 (11)	15 (5)	1 (1)
	37 (15)	0 (0)	0 (0)	37 (15)		2 (2)
8	46 (19)	0 (0)	2 (1)	44 (18)	50 (15)	6 (5)
	209 (85)	0 (0)	22 (9)	187 (76)		12 (11)
Total for Marathon Map Area:	7000 (2850)	840 (340)	119 (48)	6000 (2430)		500 (455)

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, HEMLO AREA.

1 Deposit No.	2 Area Acres (Hectares)	3 Cultural Setbacks Acres (Hectares)	4 Extracted Area Acres (Hectares)	5 Available Area Acres (Hectares)	6 Estimated Deposit Thickness Feet (Metres)	7 Available Aggregate Millions of Tons (Tonnes)
MANITOUWADGE MAP AREA						
Unsurveyed						
9	105 (42)	0 (0)	0 (0)	105 (42)	50 (15)	13 (12)
10	70 (28)	0 (0)	0 (0)	70 (28)	30 (9)	5 (5)
11	220 (89)	15 (6)	5 (2)	200 (81)	15 (5)	8 (7)
	395 (160)	15 (6)	5 (2)	375 (152)		26 (24)
Manitouwadge Township Municipality						
12a	65 (26)	10 (4)	15 (6)	40 (16)	50 (15)	5 (5)
12b	140 (57)	0 (0)	5 (2)	135 (55)	15 (5)	5 (5)
	205 (83)	10 (4)	20 (8)	175 (71)		10 (9)
13a	210 (85)	25 (10)	10 (4)	175 (71)	18 (6)	8 (7)
13b	27 (11)	0 (0)	0 (0)	27 (11)	12 (4)	1 (1)
13c	16 (6)	0 (0)	0 (0)	16 (6)	15 (5)	1 (1)
	255 (103)	25 (10)	10 (4)	218 (88)		10 (9)
14a	40 (16)	0 (0)	0 (0)	40 (16)	25 (8)	2 (2)
14b	240 (97)	0 (0)	0 (0)	240 (97)	19 (6)	11 (10)
	280 (113)	0 (0)	0 (0)	280 (113)		13 (12)
	740 (300)	35 (14)	30 (12)	670 (270)		33 (30)
Total for Manitouwadge Map Area:						
	1140 (460)	50 (20)	35 (14)	1040 (420)		59 (54)

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, HEMLO AREA.

1 Deposit No.	2 Area Acres (Hectares)	3 Cultural Setbacks Acres (Hectares)	4 Extracted Area Acres (Hectares)	5 Available Area Acres (Hectares)	6 Estimated Deposit Thickness Feet (Metres)	7 Available Aggregate Millions of Tons (Tonnes)
WHITE RIVER MAP AREA						
Unsurveyed						
15a	160 (65)	0 (0)	0 (0)	160 (65)	30 (9)	12 (11)
15b	45 (18)	0 (0)	0 (0)	45 (18)	15 (5)	2 (2)
	205 (83)	0 (0)	0 (0)	205 (83)		14 (13)
Laberge						
16	20 (8)	6 (2)	1 (0.4)	13 (5)	20 (6)	1 (1)
Bryant						
17	320 (130)	50 (20)	10 (4)	260 (105)	25 (8)	16 (15)
McCron						
17	2 (1)	0 (0)	1 (0.4)	1 (0.4)	25 (8)	<1 (<1)
Cecile						
18	60 (24)	0 (0)	0 (0)	60 (24)	25 (8)	4 (4)
19	390 (158)	40 (16)	0 (0)	350 (142)	25 (8)	22 (20)
20	40 (16)	0 (0)	1 (0.4)	39 (16)	15 (5)	1 (1)
21a	80 (32)	1 (0.4)	4 (2)	75 (30)	50 (15)	9 (8)
22	8 (3)	0 (0)	1 (0.4)	7 (3)	25 (8)	<1 (<1)
	580 (235)	41 (17)	6 (2)	530 (214)		36 (33)

TABLE 3. SELECTED SAND AND GRAVEL RESOURCE AREAS, HEMLO AREA.

1 Deposit No.	2 Area Acres (Hectares)	3 Cultural Setbacks Acres (Hectares)	4 Extracted Area Acres (Hectares)	5 Available Area Acres (Hectares)	6 Estimated Deposit Thickness Feet (Metres)	7 Available Aggregate Millions of Tons (Tonnes)
Knowles						
21b	55 (22)	0 (0)	5 (2)	50 (20)	50 (15)	6 (5)
21c	155 (63)	0 (0)	0 (0)	155 (63)	50 (15)	19 (17)
	210 (85)	0 (0)	5 (2)	205 (83)		25 (23)
22	60 (24)	0 (0)	1 (0.4)	59 (24)	25 (8)	4 (4)
	270 (109)	0 (0)	6 (2)	265 (107)		29 (26)
White River Township Municipality						
23a	90 (36)	5 (2)	35 (14)	50 (20)	30 (9)	4 (4)
23b	120 (49)	0 (0)	0 (0)	120 (49)	50 (15)	15 (14)
	210 (85)	5 (2)	35 (14)	170 (69)		19 (17)
Total for White River Area:						
	1610 (650)	102 (41)	59 (24)	1440 (580)		115 (104)
TOTAL FOR STUDY AREA:						
	9800 (3950)	990 (400)	213 (86)	8500 (3450)		670 (610)

TABLE 4. SUMMARY OF TEST HOLE DATA, HEMLO AREA.

MARATHON MAP AREA

Test Hole Number: HE-TH-1
Location: Marathon Township Municipality
Elevation: Approx. 1040 feet (315 m) a.s.l.
Date: October 22, 1983

Depth feet (metres)	Description
0-2.5 (0-0.8)	coarse **sand** with minor fine gravel
2.5-8.0 (0.8-2.4)	clean, medium to coarse **gravel** with a coarse sand matrix

Test Hole Number: HE-TH-2
Location: Marathon Township Municipality
Elevation: Approx. 1030 feet (315 m) a.s.l.
Date: October 22, 1983

Depth feet (metres)	Description
0-2.0 (0-0.6)	medium **sand**
2.0-8.0 (0.6-2.4)	clean, medium to coarse **gravel**

Test Hole Number: HE-TH-3
Location: Marathon Township Municipality
Elevation: Approx. 1020 feet (310 m) a.s.l.
Date: October 22, 1983

Depth feet (metres)	Description
0-1.5 (0-0.5)	clean, horizontally stratified medium **sand**
1.5-6.5 (0.5-2.0)	clean, fine to medium **gravel**
6.5-8.0 (2.0-2.4)	clean medium **sand**

Test Hole Number: HE-TH-4
Location: Marathon Township Municipality
Elevation: Approx. 1050 feet (320 m) a.s.l.
Date: October 22, 1983

Depth feet (metres)	Description
0-1.5 (0-0.5)	silty fine **sand**
1.5-9.0 (0.5-2.7)	slightly dirty coarse **gravel** with abundant oversize material

Test Hole Number: HE-TH-5
Location: Approx. 1.1 miles (1.8 km) east of Highway 614 near Philips Creek, floor of pit no. 55
Elevation: Approx. 1070 feet (325 m) a.s.l.
Date: October 24, 1983

Depth feet (metres)	Description
0-2.0 (0-0.6)	clean, gritty coarse **sand**
2.0-4.0 (0.6-1.2)	wet, silty fine **sand**

MANITOUWADGE MAP AREA

Test Hole Number: HE-TH-6
Location: Along Highway 614 near Amwri Creek
Elevation: Approx. 1050 feet (320 m) a.s.l.
Date: October 24, 1983

Depth feet (metres)	Description
0-2.0 (0-0.6)	ripple laminated fine **sand**
2.0-9.0 (0.6-2.7)	silty fine sand **till** with occasional boulders

Test Hole Number: HE-TH-7
Location: Approx. 0.8 mile (1.3 km) east of Highway 614 near pit no. 81
Elevation: Approx. 1030 feet (315 m) a.s.l.
Date: October 24, 1983

Depth feet (metres)	Description
0-3.0 (0-0.9)	ripple laminated fine **sand**
3.0-6.0 (0.9-1.8)	clean medium to coarse **sand** with minor fine gravel
6.0-8.0 (1.8-2.4)	clean medium **sand**

Test Hole Number: HE-TH-8
Location: Along Highway 614 near pit no. 82
Elevation: Approx. 980 feet (300 m) a.s.l.
Date: October 24, 1983

Depth feet (metres)	Description
0-6.0 (0-1.8)	varved **silt** and **clay**

TABLE 4. SUMMARY OF TEST HOLE DATA, HEMLO AREA.

WHITE RIVER MAP AREA

Test Hole Number: HE-TH-9
Location: North of Highway 17 near the western shore of White Lake
Elevation: Approx. 1080 feet (330 m) a.s.l.
Date: October 23, 1983

Depth feet (metres)	Description
0-8.5 (0-2.6)	fine to medium **sand**
8.5-9.5 (2.6-2.9)	medium to coarse **sand** with minor fine gravel

Test Hole Number: HE-TH-10
Location: Bryant Township
Elevation: Approx. 1150 feet (350 m) a.s.l.
Date: October 23, 1983

Depth feet (metres)	Description
0-3.0 (0-0.9)	medium **sand**
3.0-8.0 (0.9-2.4)	clean, sandy coarse **gravel**

Test Hole Number: HE-TH-11
Location: Knowles Township
Elevation: Approx. 1230 feet (375 m) a.s.l.
Date: October 23, 1983

Depth feet (metres)	Description
0-1.5 (0-0.5)	clean, horizontally stratified coarse **sand** with minor amounts of fine gravel
1.5-8.0 (0.5-2.4)	clean, stratified medium **sand** with minor amounts of fine gravel

Test Hole Number: HE-TH-12
Location: Knowles Township
Elevation: Approx. 1230 feet (375 m) a.s.l.
Date: October 23, 1983

Depth feet (metres)	Description
0-1.5 (0-0.5)	medium **gravel**
1.5-3.0 (0.5-0.9)	coarse **sand** and fine **gravel**
3.0-10.0 (0.9-3.0)	clean coarse **gravel**

Test Hole Number: HE-TH-13
Location: Knowles Township
Elevation: Approx. 1260 feet (385 m) a.s.l.
Date: October 23, 1983

Depth feet (metres)	Description
0-3.0 (0-0.9)	**boulders** with dirty fine sand matrix
3.0-9.0 (0.9-2.7)	clean, sandy fine to medium **gravel**

Test Hole Number: HE-TH-14
Location: Knowles Township
Elevation: Approx. 1240 feet (380 m) a.s.l.
Date: October 23, 1983

Depth feet (metres)	Description
0-2.0 (0-0.6)	slightly dirty gravelly **sand**
2.0-2.5 (0.6-0.8)	clean medium to coarse **sand**
2.5-4.0 (0.8-1.2)	clean gravelly **sand**
4.0-4.5 (1.2-1.4)	clean medium **sand**
4.5-8.0 (1.4-2.4)	clean gravelly **sand**

Test Hole Number: HE-TH-15
Location: Cecile Township
Elevation: Approx. 1230 feet (375 m) a.s.l.
Date: October 23, 1983

Depth feet (metres)	Description
0-10.0 (0-3.0)	**boulders** and very coarse **gravel** with slightly dirty medium to coarse sand matrix

Test Hole Number: HE-TH-16
Location: Cecile Township, floor of pit no. 135
Elevation: Approx. 1250 feet (380 m) a.s.l.
Date: October 23, 1983

Depth feet (metres)	Description
0-8.0 (0-2.4)	clean, well stratified, fine to medium **gravel** with a coarse sand matrix

TABLE 5. SUMMARY OF GEOPHYSICS DATA, HEMLO AREA.

MARATHON MAP AREA

Line Number: HE-GT-1
Line Direction: East-West
Method: Hammer Seismic
Location: Marathon Township Municipality
Elevation: Approx. 1050 feet (320 m) a.s.l.
Seismic Data:
Number of Layers: 1
Layer Velocities: V_1 = 1450 ft./sec. (440 m/sec.)
Interpretation: A minimum of 40 feet (12 m) of sand and gravel.

Line Number: HE-GT-2
Line Direction: East-West
Method: Hammer Seismic
Location: Marathon Township Municipality, floor of pit no. 11
Elevation: Approx. 1050 feet (320 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1 = 1140 ft./sec. (345 m/sec.)
V_2 = 12,000 ft./sec. (3650 m/sec.)
Layer Thickness: D_1 = 34 ft. (10 m)
Interpretation: Approx. 34 feet (10 m) of sand and gravel over bedrock.

Line Number: HE-GT-3
Line Direction: Northeast-Southwest
Method: Hammer Seismic
Location: Marathon Township Municipality
Elevation: Approx. 1000 feet (305 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1 = 1140 ft./sec. (345 m/sec.)
V_2 = 9000 ft./sec. (2750 m/sec.)
Layer Thickness: D_1 = 24 ft. (7 m)
Interpretation: Approx. 24 feet (7 m) of sand and cobbly gravel over an irregular bedrock surface.

Line Number: HE-GT-4
Line Direction: Northwest-Southeast
Method: Hammer Seismic
Location: Marathon Township Municipality
Elevation: Approx. 1070 feet (325 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1 = 1090 ft./sec. (330 m/sec.)
V_2 = 1780 ft./sec. (540 m/sec.)
Layer Thickness: D_1 = 12 ft. (4 m)
Interpretation: Approx. 12 feet (4 m) of loose sand and gravel over denser sand and gravel to a minimum of 40 feet (12 m).

Line Number: HE-GT-5
Line Direction: Northwest-Southeast
Method: Hammer Seismic
Location: Marathon Township Municipality
Elevation: Approx. 1040 feet (315 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1 = 1430 ft./sec. (435 m/sec.)
V_2 = 2800 ft./sec. (850 m/sec.)
Layer Thickness: D_1 = 10 ft. (3 m)
Interpretation: Approx. 10 feet (3 m) of loose sandy gravel over denser sand and gravel to a minimum depth of 40 feet (12 m).

Line Number: HE-GT-6
Line Direction: Northwest-Southeast
Method: Hammer Seismic
Location: Marathon Township Municipality, floor of pit no. 18
Elevation: Approx. 730 feet (222 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1 = 1330 ft./sec. (405 m/sec.)
V_2 = 4650 ft./sec. (1420 m/sec.)
Layer Thickness: D_1 = 5 ft. (1.5 m)
Interpretation: Approx. 5 feet (1.5 m) of dry sand and gravel over wet sand and gravel to a minimum of 40 feet (12 m).

TABLE 5. SUMMARY OF GEOPHYSICS DATA, HEMLO AREA.

Line Number: HE-GT-7
Line Direction: East-West
Method: Hammer Seismic
Location: Marathon Township Municipality
Elevation: Approx. 730 feet (222 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1= 1250 ft./sec. (380 m/sec.)
V_2= 3350 ft./sec. (1020 m/sec.)
Layer Thickness: D_1= 9 ft. (3 m)

Interpretation: Approx. 9 feet (3 m) of loose sand and gravel over denser sand and gravel to a minimum of 40 feet (12 m).

Line Number: HE-GT-8
Line Direction: Northwest-Southeast
Method: Hammer Seismic
Location: Marathon Township Municipality
Elevation: Approx. 750 feet (229 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1= 1250 ft./sec. (380 m/sec.)
V_2= 20,000 ft./sec. (6100 m/sec.)
Layer Thickness: D_1= 15 ft. (5 m)

Interpretation: Approx. 15 feet (5 m) of sand and gravel over bedrock.

Line Number: HE-GT-9
Line Direction: North-South
Method: Hammer Seismic
Location: Marathon Township Municipality
Elevation: Approx. 930 feet (285 m) a.s.l.
Seismic Data:
Number of Layers: 1
Layer Velocities: V_1= 1140 ft./sec (345 m/sec.)

Interpretation: A minimum of 40 feet (12 m) of sand and gravel.

Line Number: HE-GT-10
Line Direction: Northeast-Southwest
Method: Hammer Seismic
Location: Marathon Township Municipality
Elevation: Approx. 1020 feet (310 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1= 1140 ft./sec. (345 m/sec.)
V_2= 2500 ft./sec. (760 m/sec.)
Layer Thickness: D_1= 6 ft. (1.8 m)

Interpretation: Approx. 6 feet (1.8 m) of loose sand and gravel over denser sand and gravel to a minimum of 40 feet (12 m).

Line Number: HE-GT-11
Line Direction: North-South
Method: Hammer Seismic
Location: Marathon Township Municipality
Elevation: Approx. 1030 feet (315 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1= 1000 ft./sec. (305 m/sec.)
V_2= 2000 ft./sec. (610 m/sec.)
Layer Thickness: D_1= 11 ft. (3 m)

Interpretation: Approx. 11 feet (3 m) of loose sand and gravel over denser sand and gravel to a minimum of 40 feet (12 m).

Line Number: HE-GT-12
Line Direction: East-West
Method: Hammer Seismic
Location: Marathon Township Municipality
Elevation: Approx. 1030 feet (315 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1= 1200 ft./sec. (365 m/sec.)
V_2= 26,000 ft./sec. (7900 m/sec.)
Layer Thickness: D_1= 24 ft. (7 m)

Interpretation: Approx. 24 feet (7 m) of sand over an irregular bedrock surface.

Line Number: HE-GT-13
Line Direction: Northwest-Southeast
Method: Hammer Seismic
Location: Marathon Township Municipality
Elevation: Approx. 1030 feet (315 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1= 1110 ft./sec. (340 m/sec.)
V_2= 2670 ft./sec. (810 m/sec.)
Layer Thickness: D_1= 8 ft. (2 m)

Interpretation: Approx. 8 feet (2 m) of loose sandy gravel over denser sand and gravel to a minimum of 40 feet (12 m).

TABLE 5. SUMMARY OF GEOPHYSICS DATA, HEMLO AREA.

Line Number: HE-GT-14

Line Direction: Northwest-Southeast

Method: Hammer Seismic

Location: Marathon Township Municipality

Elevation: Approx. 1020 feet (310 m) a.s.l.

Seismic Data:

Number of Layers: 2
Layer Velocities: V_1 = 1250 ft./sec. (380 m/sec.)
V_2 = 5000 ft./sec. (1520 m/sec.)
Layer Thickness: D_1 = 36 ft. (11 m)

Interpretation: Approx. 36 feet (11 m) of dry sand and gravel over wet sand and gravel to a minimum of 40 feet (12 m).

Line Number: HE-GT-15

Line Direction: Northwest-Southeast

Method: Hammer Seismic

Location: Marathon Township Municipality

Elevation: Approx. 1000 feet (305 m) a.s.l.

Seismic Data:

Number of Layers: 2
Layer Velocities: V_1 = 920 ft./sec. (280 m/sec.)
V_2 = 1600 ft./sec. (490 m/sec.)
Layer Thickness: D_1 = 5 ft. (1.5 m)

Interpretation: Approx. 5 feet (1.5 m) of loose sand and gravel over denser sand and gravel to a minimum depth of 40 feet (12 m).

Line Number: HE-GT-16

Line Direction: Northeast-Southwest

Method: Hammer Seismic

Location: Pic Township

Elevation: Approx. 930 feet (285 m) a.s.l.

Seismic Data:

Number of Layers: 2
Layer Velocities: V_1 = 1660 ft./sec. (510 m/sec.)
V_2 = 24,800 ft./sec. (7600 m/sec.)
Layer Thickness: D_1 = 18 ft. (5 m)

Interpretation: Approx. 18 feet (5 m) of sandy gravel over an irregular bedrock surface.

Line Number: HE-GT-17

Line Direction: North-South

Method: Hammer Seismic

Location: Approx. 0.6 mile (1 km) west of Highway 614 along Philips Creek

Elevation: Approx. 1030 feet (315 m) a.s.l.

Seismic Data:

Number of Layers: 3
Layer Velocities: V_1 = 1250 ft./sec. (380 m/sec.)
V_2 = 2330 ft./sec. (710 m/sec.)
V_3 = 5500 ft./sec. (1680 m/sec.)
Layer Thickness: D_1 = 6 ft. (1.8 m)
D_2 = 9 ft. (3 m)

Interpretation: Approx. 6 feet (1.8 m) of a loose mixture of sand, gravel, and till which becomes denser between 6 and 15 feet (1.8 and 5 m). Below 15 feet (5 m) the material becomes wet.

MANITOUWADGE MAP AREA

Line Number: HE-GT-18

Line Direction: Northeast-Southwest

Method: Hammer Seismic

Location: Near pit no. 81

Elevation: Approx. 1020 feet (310 m) a.s.l.

Seismic Data:

Number of Layers: 2
Layer Velocities: V_1 = 1110 ft./sec. (340 m/sec.)
V_2 = 26,000 ft./sec. (7900 m/sec.)
Layer Thickness: D_1 = 19 ft. (6 m)

Interpretation: Approx. 19 feet (6 m) of loose sand and gravel over bedrock.

Line Number: HE-GT-19

Line Direction: Northeast-Southwest

Method: Hammer Seismic

Location: Between pit nos. 81 and 85

Elevation: Approx. 1020 feet (310 m) a.s.l.

Seismic Data:

Number of Layers: 2
Layer Velocities: V_1 = 1400 ft./sec. (425 m/sec.)
V_2 = 16,000 ft./sec. (4900 m/sec.)
Layer Thickness: D_1 = 16 ft. (5 m)

Interpretation: Approx. 16 feet (5 m) of sand over bedrock.

TABLE 5. SUMMARY OF GEOPHYSICS DATA, HEMLO AREA.

Line Number: HE-GT-20
Line Direction: North-South
Method: Hammer Seismic
Location: Floor of pit no. 82 along Highway 614
Elevation: Approx. 1030 feet (315 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1= 1470 ft./sec. (450 m/sec.)
V_2= 5000 ft./sec. (1520 m/sec.)
Layer Thickness: D_1= 32 ft. (10 m)

Interpretation: Approx. 32 feet (10 m) of dry sand and silt over moist sand and silt to a minimum depth of 40 feet (12 m).

Line Number: HE-GT-21
Line Direction: Northwest-Southeast
Method: Hammer Seismic
Location: Floor of pit no. 84 along Highway 614
Elevation: Approx. 1050 feet (320 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1= 2000 ft./sec. (610 m/sec.)
V_2= 14,000 ft./sec. (4250 m/sec.)
Layer Thickness: D_1= 11 ft. (3 m)

Interpretation: Approx. 11 feet (3 m) of gravelly sand over bedrock.

Line Number: HE-GT-22
Line Direction: North-South
Method: Hammer Seismic
Location: Manitouwadge Township Municipality
Elevation: Approx. 1030 feet (315 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1= 1400 ft./sec. (425 m/sec.)
V_2= 5000 ft./sec. (1520 m/sec.)
Layer Thickness: D_1= 18 ft. (5 m)

Interpretation: Approx. 18 feet (5 m) of dry sand over wet sand to a minimum of 40 feet (12 m).

Line Number: HE-GT-23
Line Direction: Northeast-Southwest
Method: Hammer Seismic
Location: Manitouwadge Township Municipality, floor of pit no. 100
Elevation: Approx. 1080 feet (330 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1= 1430 ft./sec. (435 m/sec.)
V_2= 7000 ft./sec. (2130 m/sec.)
Layer Thickness: D_1= 21 ft. (6 m)

Interpretation: Approx. 21 feet (6 m) of sand and gravel over bedrock.

WHITE RIVER MAP AREA

Line Number: HE-GT-24
Line Direction: Northeast-Southwest
Method: Hammer Seismic
Location: North of Highway 17 near the western shore of White Lake
Elevation: Approx. 1080 feet (330 m) a.s.l.
Seismic Data:
Number of Layers: 3
Layer Velocities: V_1= 1330 ft./sec. (405 m/sec.)
V_2= 2800 ft./sec. (850 m/sec.)
V_3= 20,000 ft./sec. (6100 m/sec.)
Layer Thickness: D_1= 6 ft. (1.8 m)
D_2= 33 ft. (10 m)

Interpretation: Approx. 6 feet (1.8 m) of loose sand over 33 feet (10 m) of denser sand over bedrock.

Line Number: HE-GT-25
Line Direction: Northwest-Southeast
Method: Hammer Seismic
Location: McCron Township
Elevation: Approx. 1330 feet (405 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1= 1140 ft./sec. (345 m/sec.)
V_2= 4650 ft./sec. (1420 m/sec.)
Layer Thickness: D_1= 21 ft. (6 m)

Interpretation: Approx. 21 feet (6 m) of dry sand and gravel over wet sand and gravel to a minimum of 40 feet (12 m).

TABLE 5. SUMMARY OF GEOPHYSICS DATA, HEMLO AREA.

Line Number: HE-GT-26
Line Direction: North-South
Method: Hammer Seismic
Location: Bryant Township
Elevation: Approx. 1150 feet (350 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1= 1110 ft./sec. (340 m/sec.)
V_2= 3500 ft./sec. (1070 m/sec.)
Layer Thickness: D_1= 14 ft. (4 m)

Interpretation: Approx. 14 feet (4 m) of loose sandy gravel over denser sand and gravel to a minimum of 40 feet (12 m).

Line Number: HE-GT-27
Line Direction: Northeast-Southwest
Method: Hammer Seismic
Location: Knowles Township
Elevation: Approx. 1230 feet (375 m) a.s.l.
Seismic Data:
Number of Layers: 3
Layer Velocities: V_1= 1110 ft./sec. (340 m/sec.)
V_2= 2000 ft./sec. (610 m/sec.)
V_3= 10,000 ft./sec. (3050 m/sec.)
Layer Thickness: D_1= 8 ft. (2 m)
D_2= 21 ft. (6 m)

Interpretation: Approx. 8 feet (2 m) of loose sand over 21 feet (6 m) of denser sand and gravel over an irregular bedrock surface.

Line Number: HE-GT-28
Line Direction: Northeast-Southwest
Method: Hammer Seismic
Location: Knowles Township
Elevation: Approx. 1230 feet (375 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1= 500 ft./sec. (152 m/sec.)
V_2= 1000 ft./sec. (305 m/sec.)
Layer Thickness: D_1= 3 ft. (1 m)

Interpretation: Approx. 3 feet (1 m) of loose topsoil over sandy gravel to a minimum depth of 25 feet (8 m).

Line Number: HE-GT-29
Line Direction: East-West
Method: Hammer Seismic
Location: Knowles Township
Elevation: Approx. 1250 feet (380 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1= 880 ft./sec. (270 m/sec.)
V_2= 1330 ft./sec. (405 m/sec.)
Layer Thickness: D_1= 7 ft. (2 m)

Interpretation: Approx. 7 feet (2 m) of loose sand and gravel over denser sand and gravel to a minimum depth of 30 feet (9 m).

Line Number: HE-GT-30
Line Direction: Northeast-Southwest
Method: Hammer Seismic
Location: Knowles Township
Elevation: Approx. 1230 feet (375 m) a.s.l.
Seismic Data:
Number of Layers: 3
Layer Velocities: V_1= 1330 ft./sec. (405 m/sec.)
V_2= 4000 ft./sec. (1220 m/sec.)
V_3= 20,000 ft./sec. (6100 m/sec.)
Layer Thickness: D_1= 11 ft. (3 m)
D_2= 20 ft. (6 m)

Interpretation: Approx. 11 feet (3 m) of loose sand and gravel over 20 feet (6 m) of denser sand and gravel over an irregular bedrock surface.

Line Number: HE-GT-31
Line Direction: Northeast-Southwest
Method: Hammer Seismic
Location: Cecile Township, floor of pit no. 129
Elevation: Approx. 1240 feet (380 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1= 1100 ft./sec. (335 m/sec.)
V_2= 16,000 ft./sec. (4900 m/sec.)
Layer Thickness: D_1= 19 ft. (6 m)

Interpretation: Approx. 19 feet (6 m) of sandy gravel over bedrock.

TABLE 5. SUMMARY OF GEOPHYSICS DATA, HEMLO AREA.

Line Number: HE-GT-32
Line Direction: Northeast-Southwest
Method: Hammer Seismic
Location: Knowles Township
Elevation: Approx. 1260 feet (385 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1 = 1110 ft./sec. (340 m/sec.)
V_2 = 2700 ft./sec. (820 m/sec.)
Layer Thickness: D_1 = 6 ft. (1.8 m)
Interpretation: Approx. 6 feet (1.8 m) of bouldery gravel over sandy gravel to a minimum depth of 40 feet (12 m).

Line Number: HE-GT-33
Line Direction: North-South
Method: Hammer Seismic
Location: Knowles Township
Elevation: Approx. 1250 feet (380 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1 = 1000 ft./sec. (305 m/sec.)
V_2 = 1600 ft./sec. 490 m/sec.)
Layer Thickness: D_1 = 12 ft. (4 m)
Interpretation: Approx. 12 feet (4 m) of loose sand over denser sand to a minimum depth of 40 feet (12 m).

Line Number: HE-GT-34
Line Direction: East-West
Method: Hammer Seismic
Location: Knowles Township
Elevation: Approx. 1220 feet (370 m) a.s.l.
Seismic Data:
Number of Layers: 3
Layer Velocities: V_1 = 1140 ft./sec. (345 m/sec.)
V_2 = 2290 ft./sec. (700 m/sec.)
V_3 = 10,000 ft./sec. (3050 m/sec.)
Layer Thickness: D_1 = 13 ft. (4 m)
D_2 = 21 ft. (6 m)
Interpretation: Approx. 13 feet (4 m) of sand and gravel over 21 feet (6 m) of denser sand and gravel over bedrock.

Line Number: HE-GT-35
Line Direction: Northeast-Southwest
Method: Hammer Seismic
Location: Knowles Township
Elevation: Approx. 1230 feet (375 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1 = 1000 ft./sec. (305 m/sec.)
V_2 = 5000 ft./sec. (1520 m/sec.)
Layer Thickness: D_1 = 22 ft. (7 m)
Interpretation: Approx. 22 feet (7 m) of dry sand and gravel overlying wet sand and gravel to a minimum depth of 40 feet (12 m).

Line Number: HE-GT-36
Line Direction: North-South
Method: Hammer Seismic
Location: Boundary of Knowles and Cecile Townships
Elevation: Approx. 1230 feet (375 m) a.s.l.
Seismic Data:
Number of Layers: 3
Layer Velocities: V_1 = 890 ft./sec. (270 m/sec.)
V_2 = 1330 ft./sec. (405 m/sec.)
V_3 = 1780 ft./sec. (540 m/sec.)
Layer Thickness: D_1 = 4 ft. (1.2 m)
D_2 = 8 ft. (2 m)
Interpretation: A minimum of 40 feet (12 m) of sand and gravel becoming denser with depth.

Line Number: HE-GT-37
Line Direction: Northeast-Southwest
Method: Hammer Seismic
Location: Cecile Township
Elevation: Approx. 1210 feet (370 m) a.s.l.
Seismic Data:
Number of Layers: 2
Layer Velocities: V_1 = 1430 ft./sec. (435 m/sec.)
V_2 = 4400 ft./sec. (1340 m/sec.)
Layer Thickness: D_1 = 10 ft. (3 m)
Interpretation: Approx. 10 feet (3 m) of dry sand over moist sand and gravel.

TABLE 5. SUMMARY OF GEOPHYSICS DATA, HEMLO AREA.

Line Number: HE-GT-38
Line Direction: North-South
Method: Hammer Seismic
Location: Cecile Township
Elevation: Approx. 1230 feet (375 m) a.s.l.
Seismic Data:

Number of Layers:	2
Layer Velocities:	V_1 = 1670 ft./sec. (510 m/sec.) V_2 = 2650 ft./sec. (810 m/sec.)
Layer Thickness:	D_1 = 9 ft. (3 m)

Interpretation: Approx. 9 feet (3 m) of dry, bouldery gravel overlying dry sand and gravel to a minimum depth of 40 feet (12 m).

Line Number: HE-GT-39
Line Direction: Northeast-Southwest
Method: Hammer Seismic
Location: Cecile Township, floor of pit no. 135
Elevation: Approx. 1250 feet (380 m) a.s.l.
Seismic Data:

Number of Layers:	2
Layer Velocities:	V_1 = 1000 ft./sec. (305 m/sec.) V_2 = 3100 ft./sec. (940 m/sec.)
Layer Thickness:	D_1 = 7 ft. (2 m)

Interpretation: Approx. 7 feet (2 m) of dry, loose, sandy gravel over denser sand and gravel or till to a minimum depth of 40 feet (12 m).

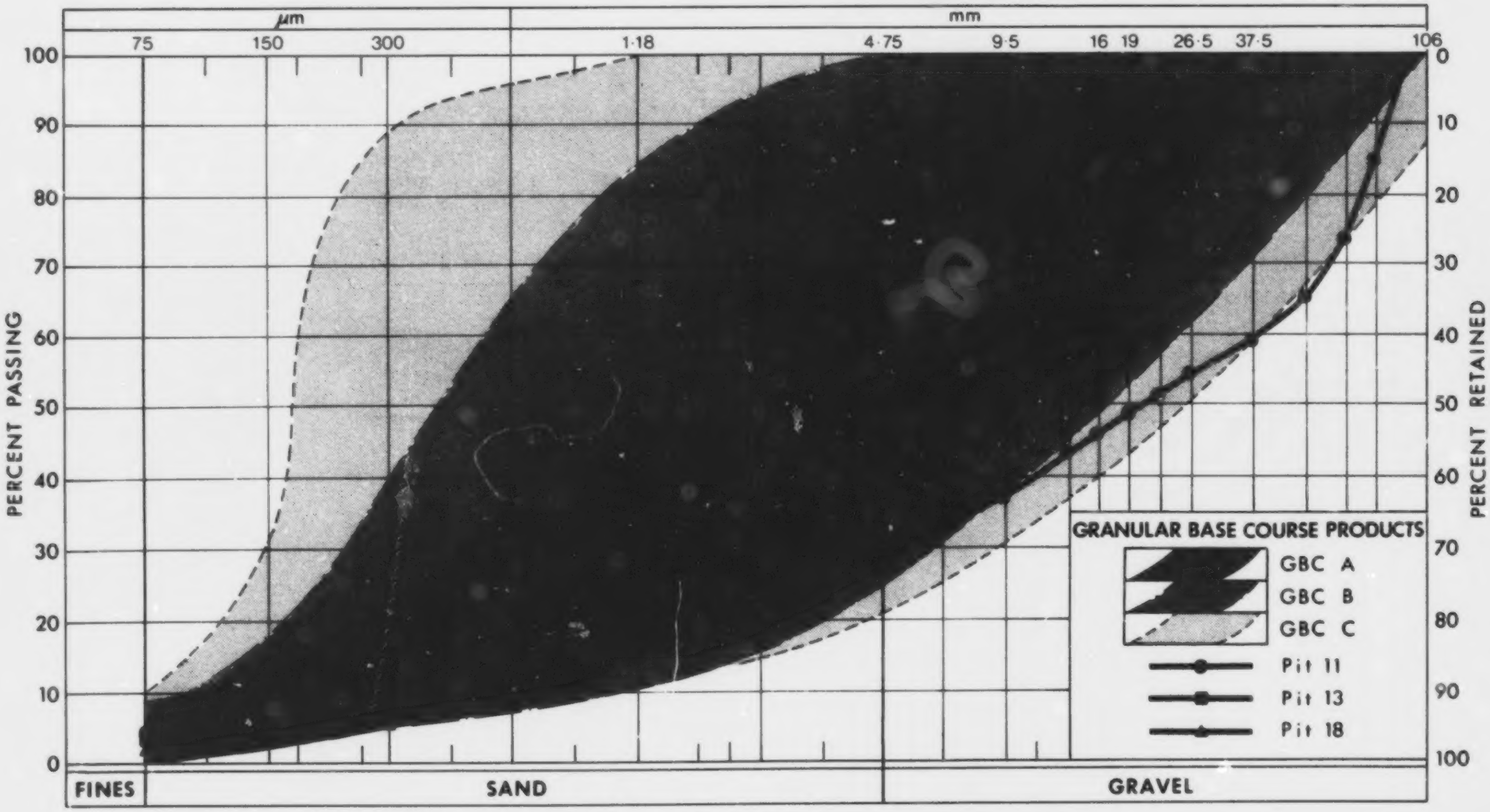


FIGURE 3a: AGGREGATE GRADING CURVES, MARATHON MAP AREA;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

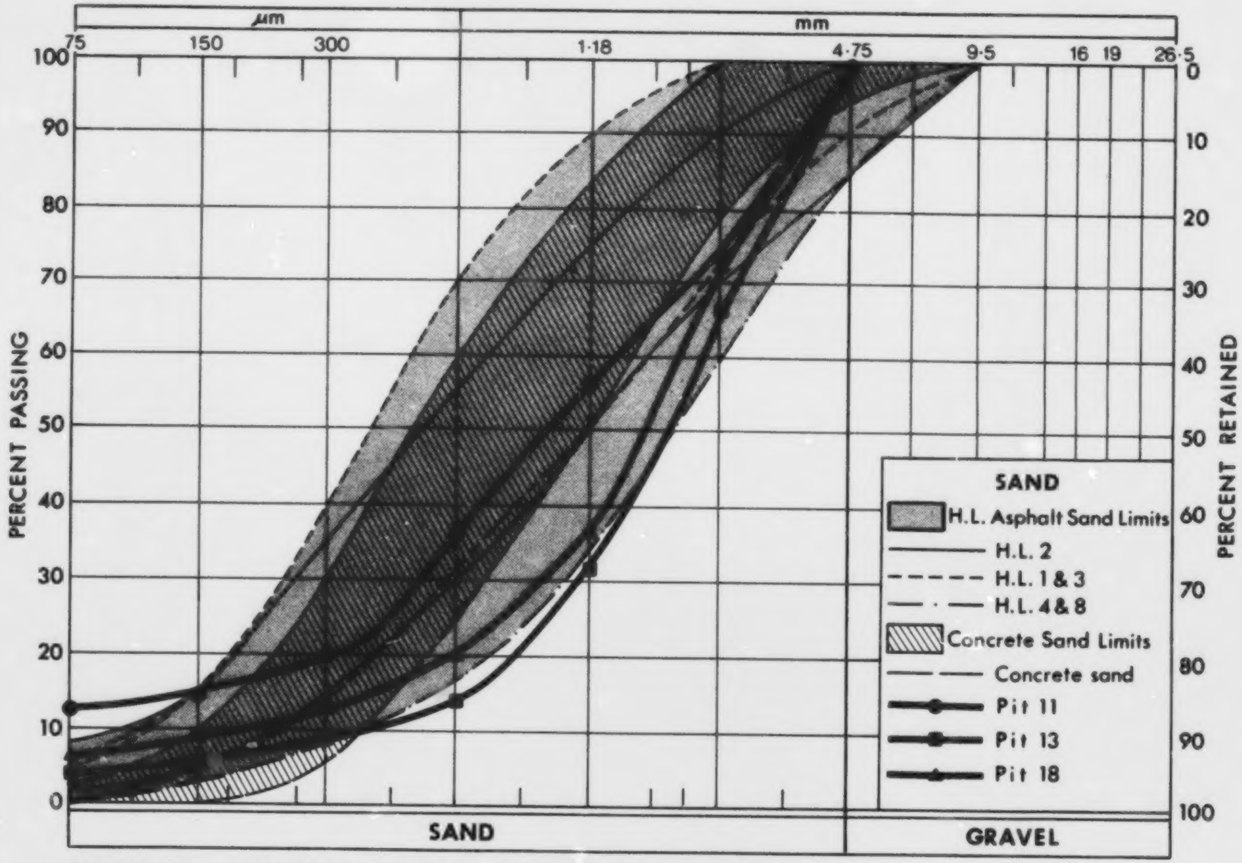


FIGURE 3b: AGGREGATE GRADING CURVES, MARATHON MAP AREA;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

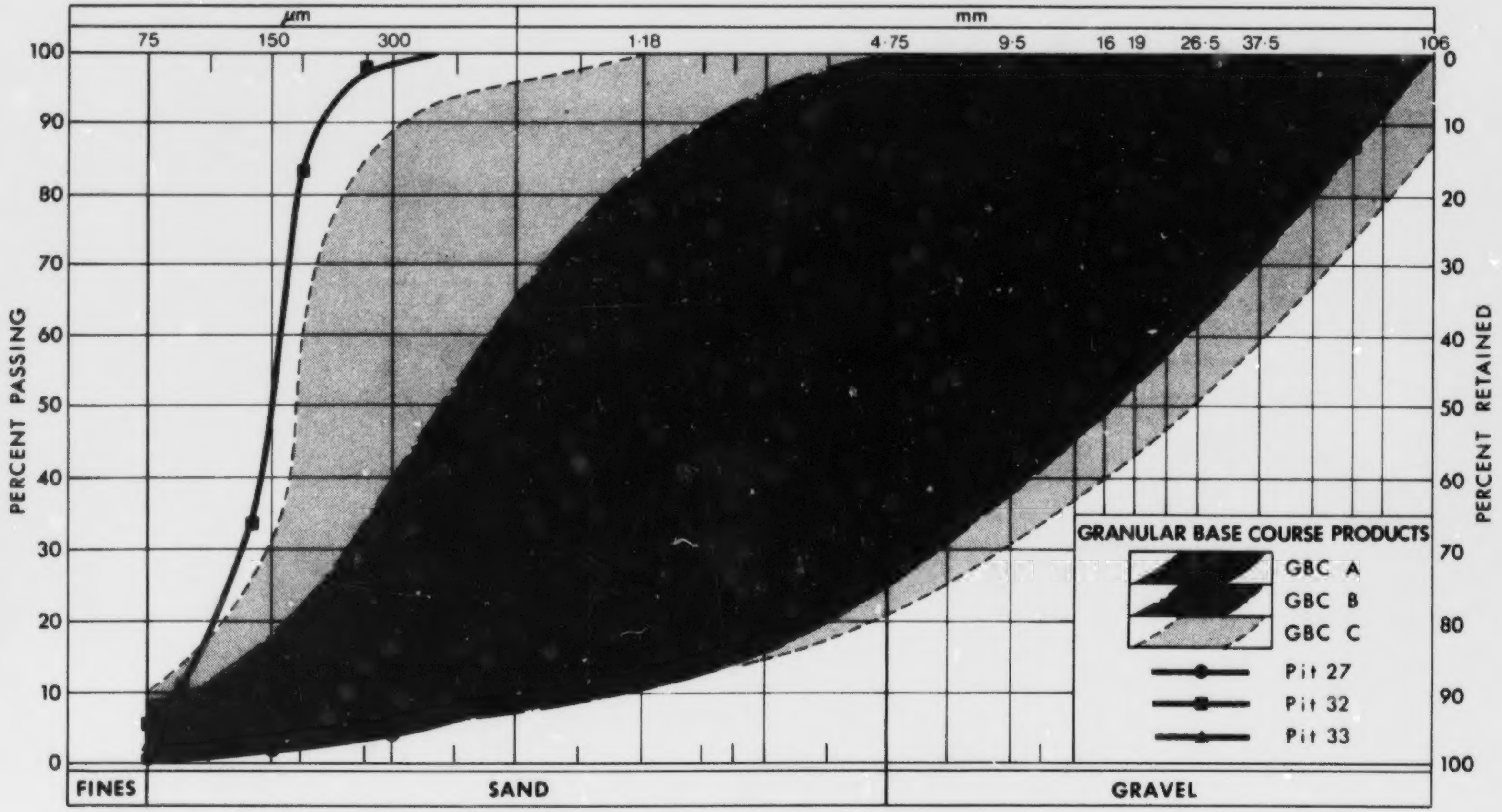


FIGURE 4a: AGGREGATE GRADING CURVES, MARATHON MAP AREA:

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

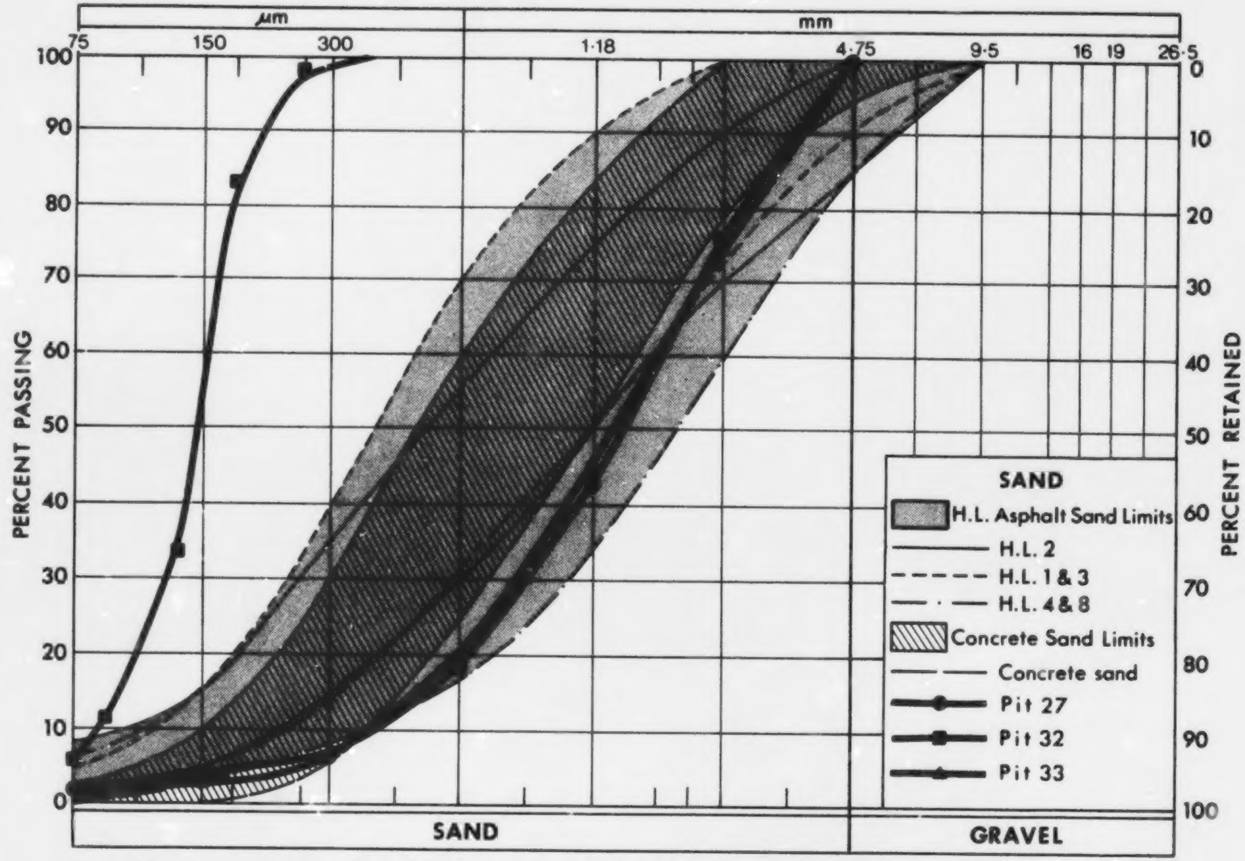


FIGURE 4b: AGGREGATE GRADING CURVES, MARATHON MAP AREA;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

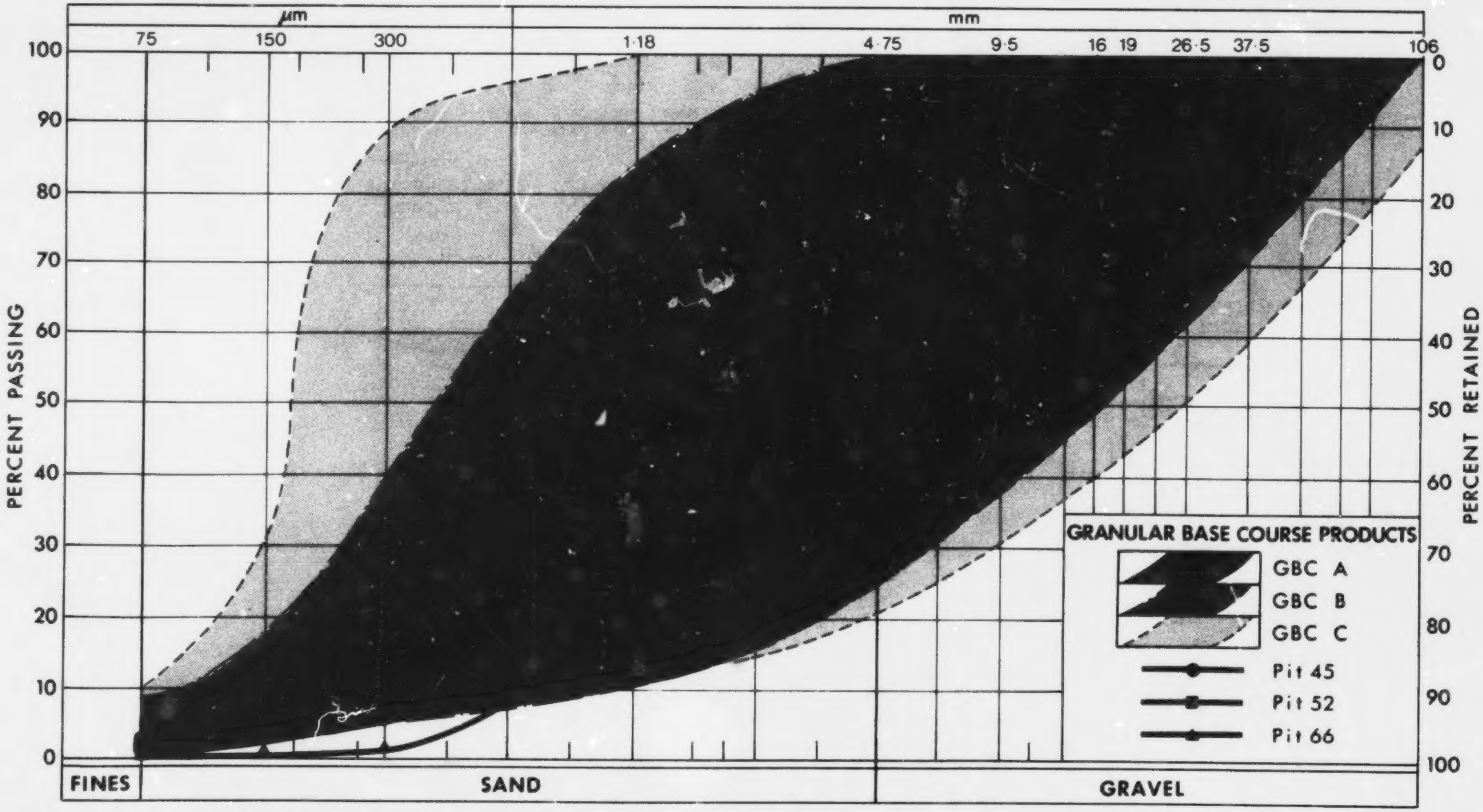


FIGURE 5a: AGGREGATE GRADING CURVES, MARATHON MAP AREA;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

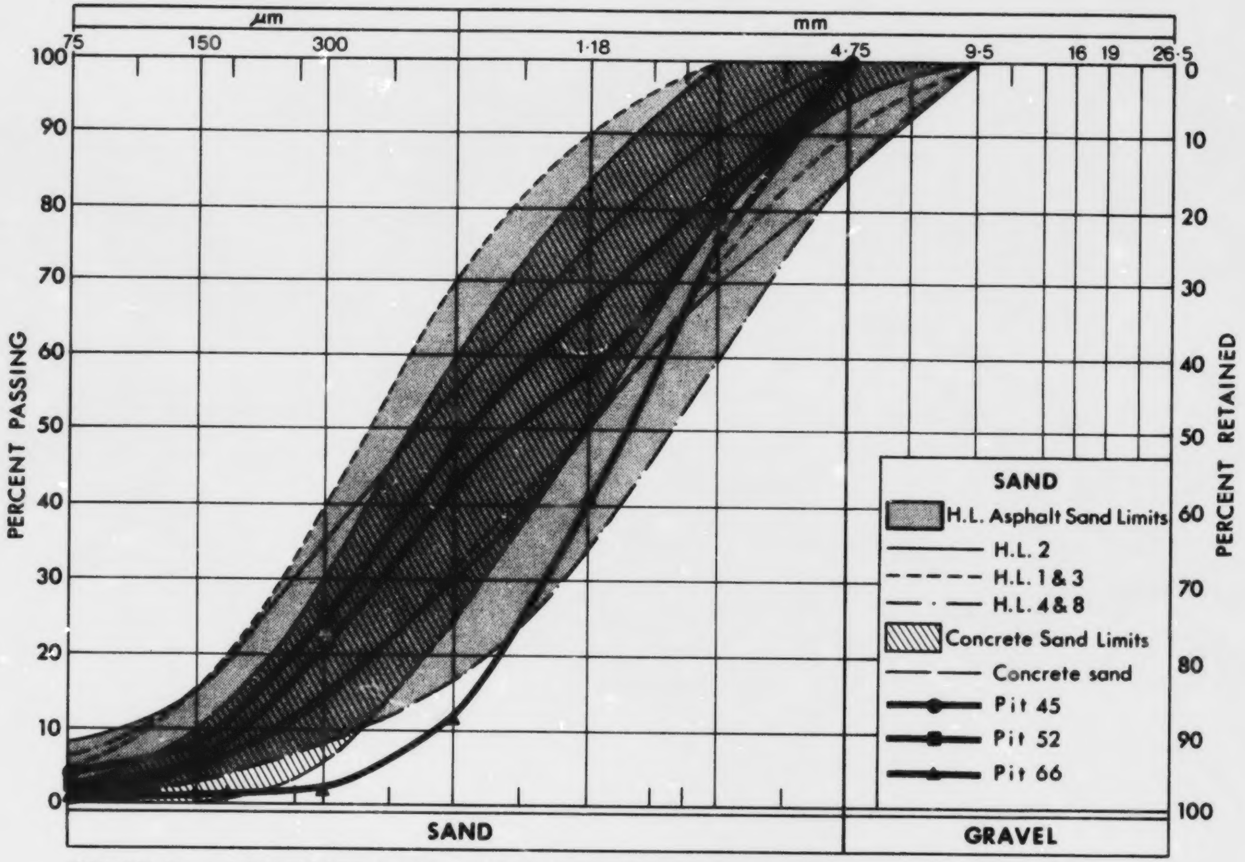


FIGURE 5b: AGGREGATE GRADING CURVES, MARATHON MAP AREA;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

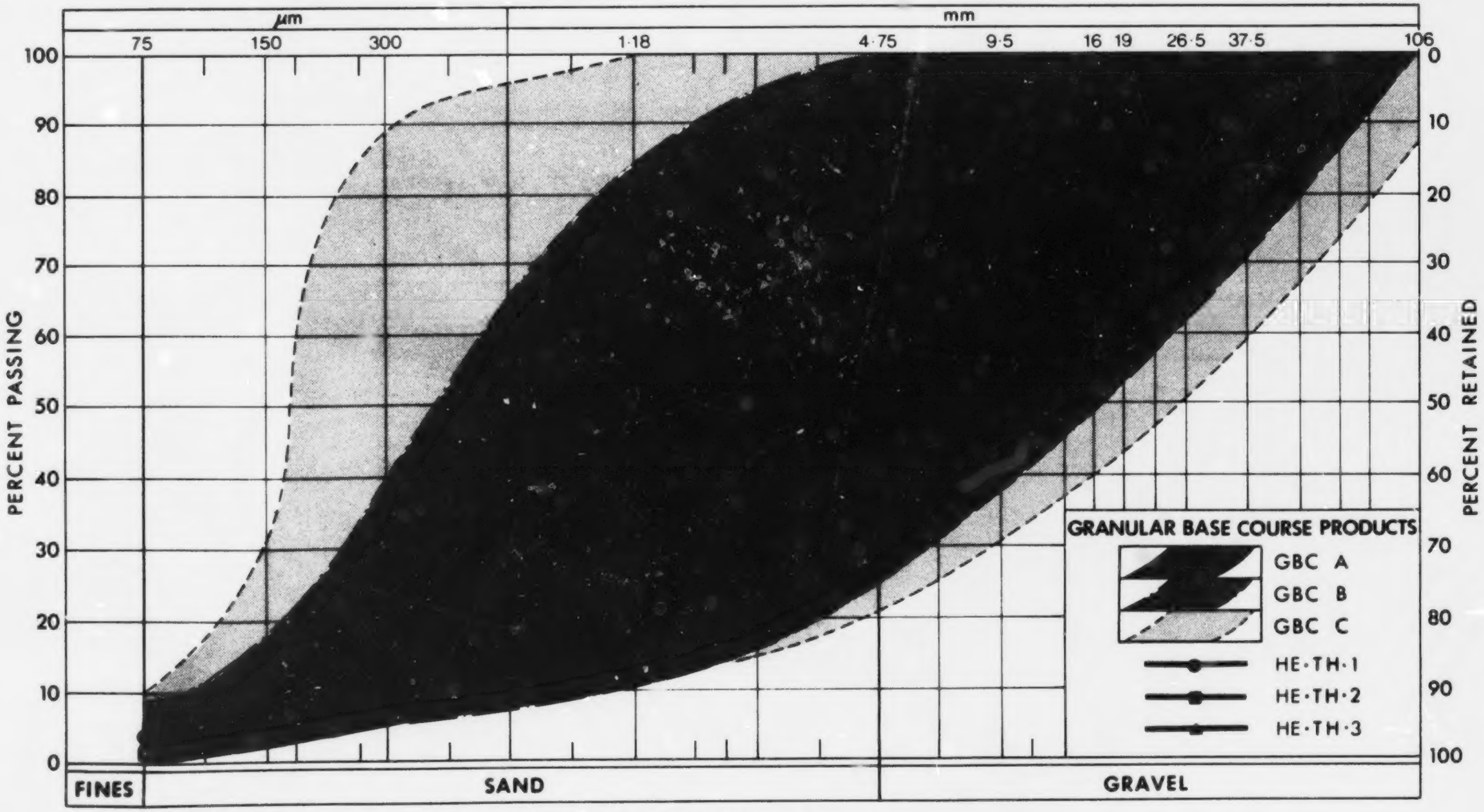


FIGURE 6a: AGGREGATE GRADING CURVES, MARATHON MAP AREA:

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

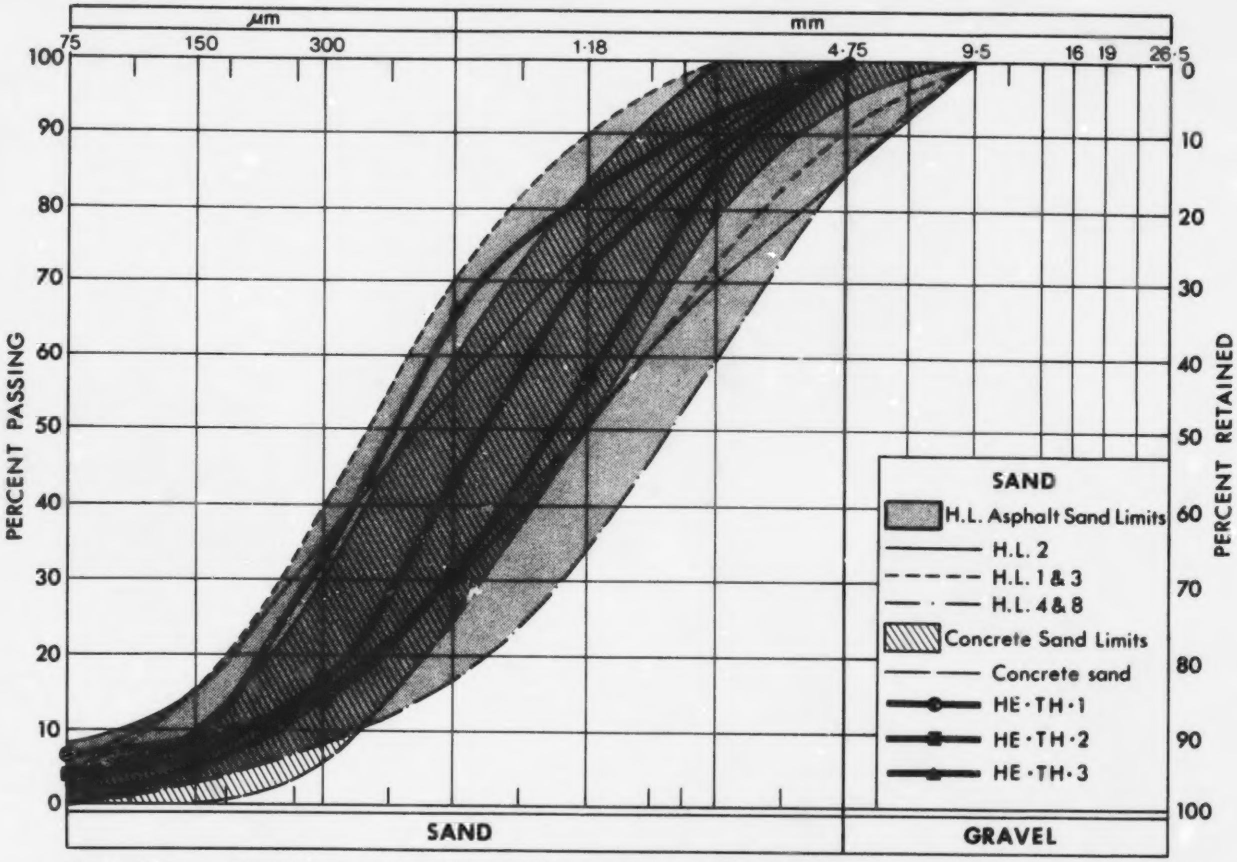


FIGURE 6b: AGGREGATE GRADING CURVES, MARATHON MAP AREA;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

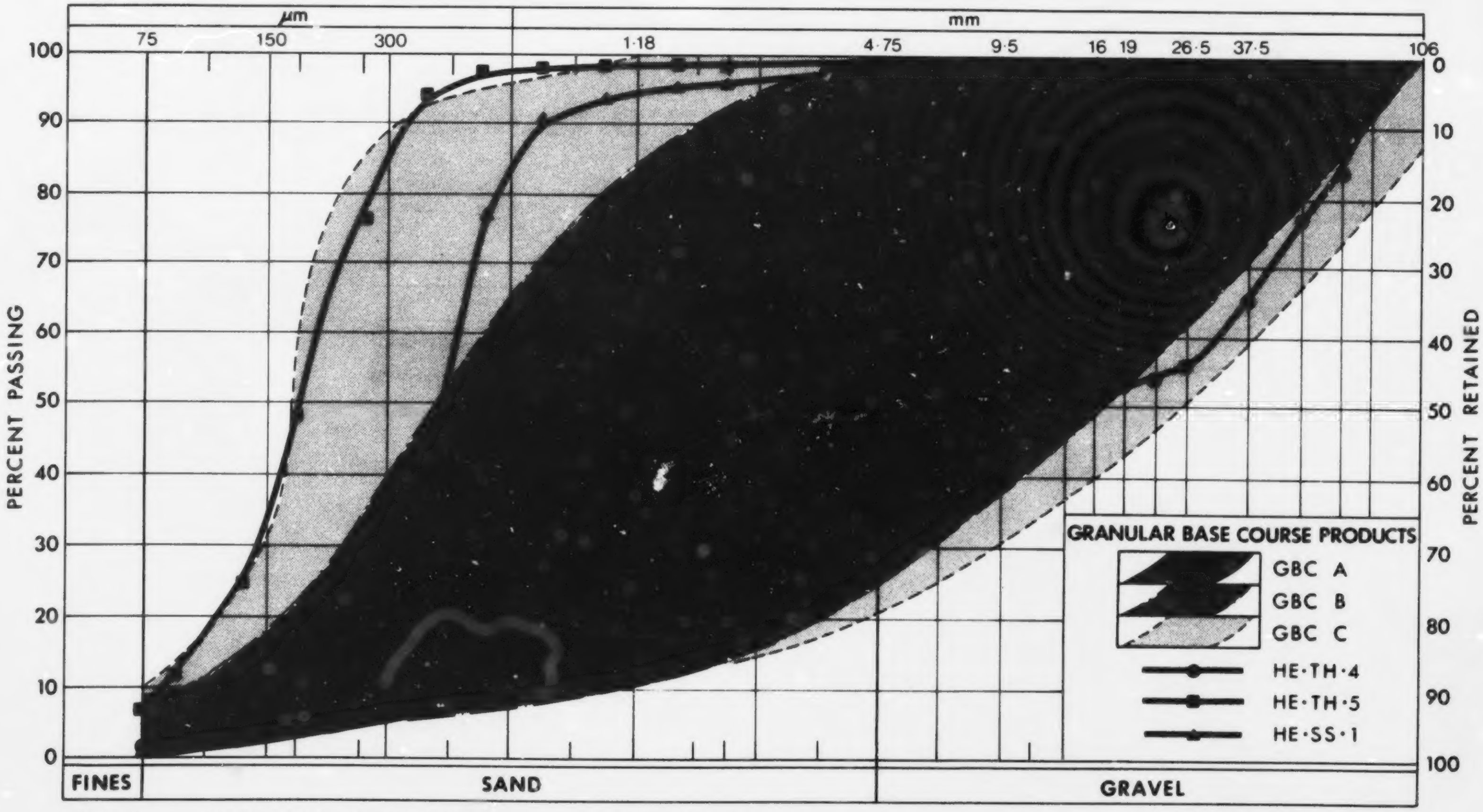


FIGURE 7a: AGGREGATE GRADING CURVES, MARATHON MAP AREA;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

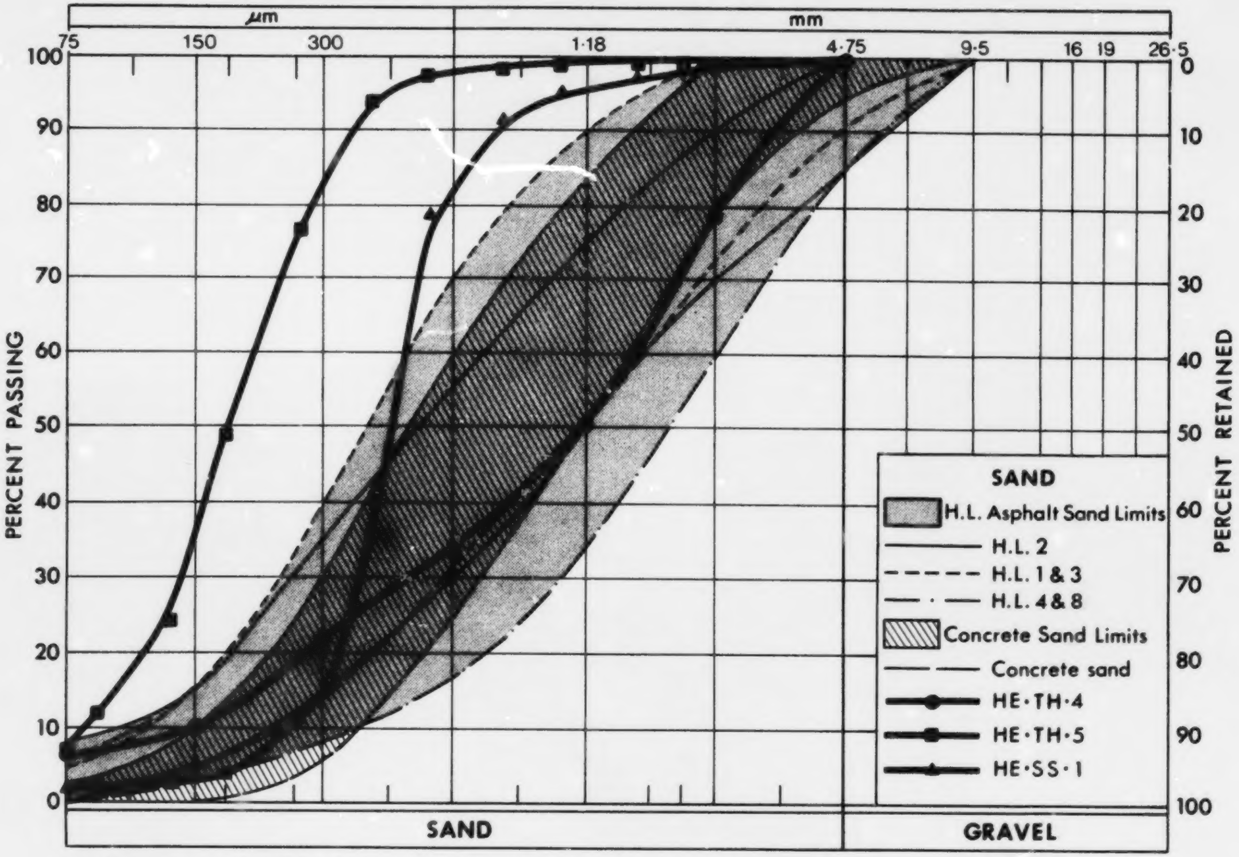


FIGURE 7b: AGGREGATE GRADING CURVES, MARATHON MAP AREA;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

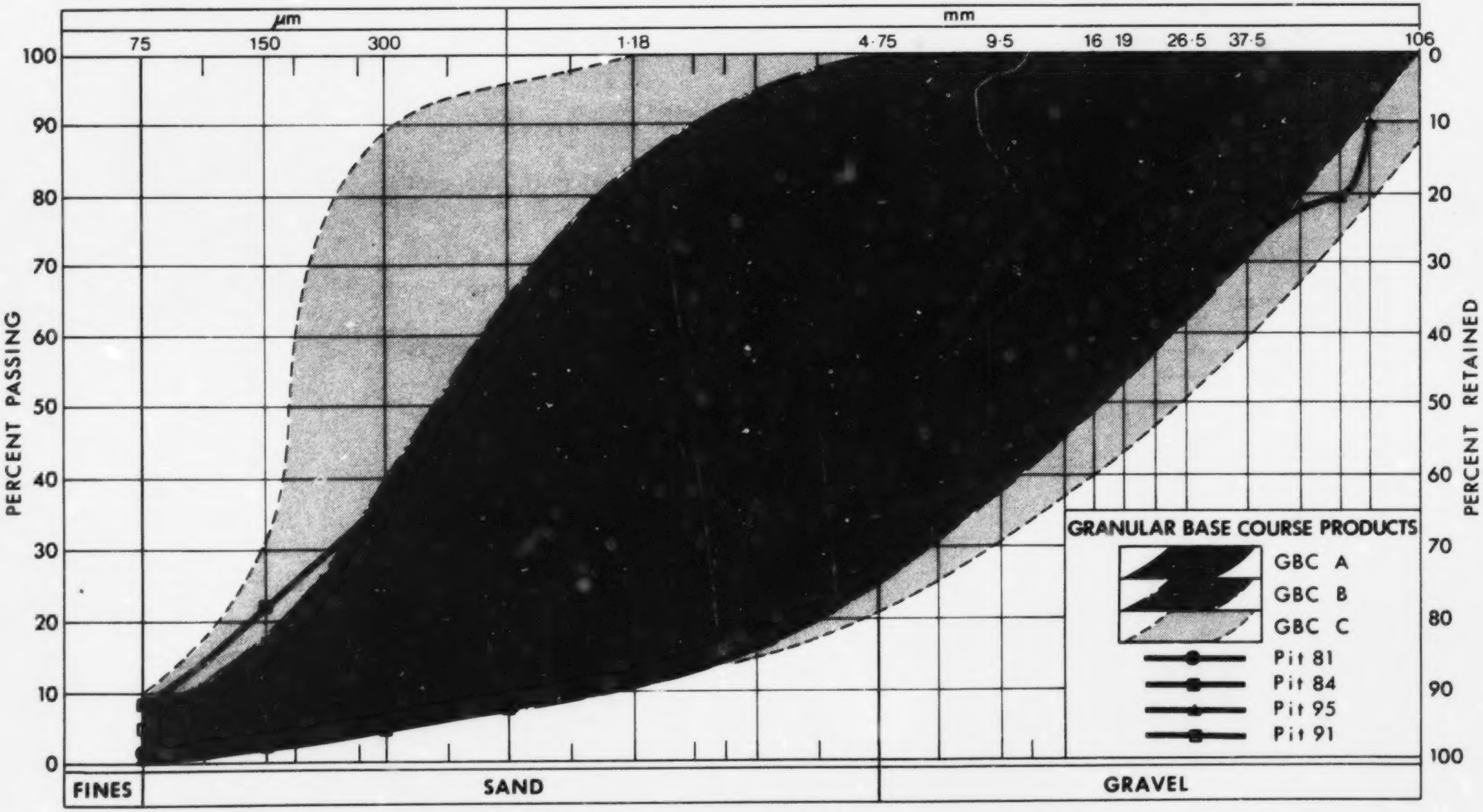


FIGURE 8a: AGGREGATE GRADING CURVES, MANITOUWADGE MAP AREA;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

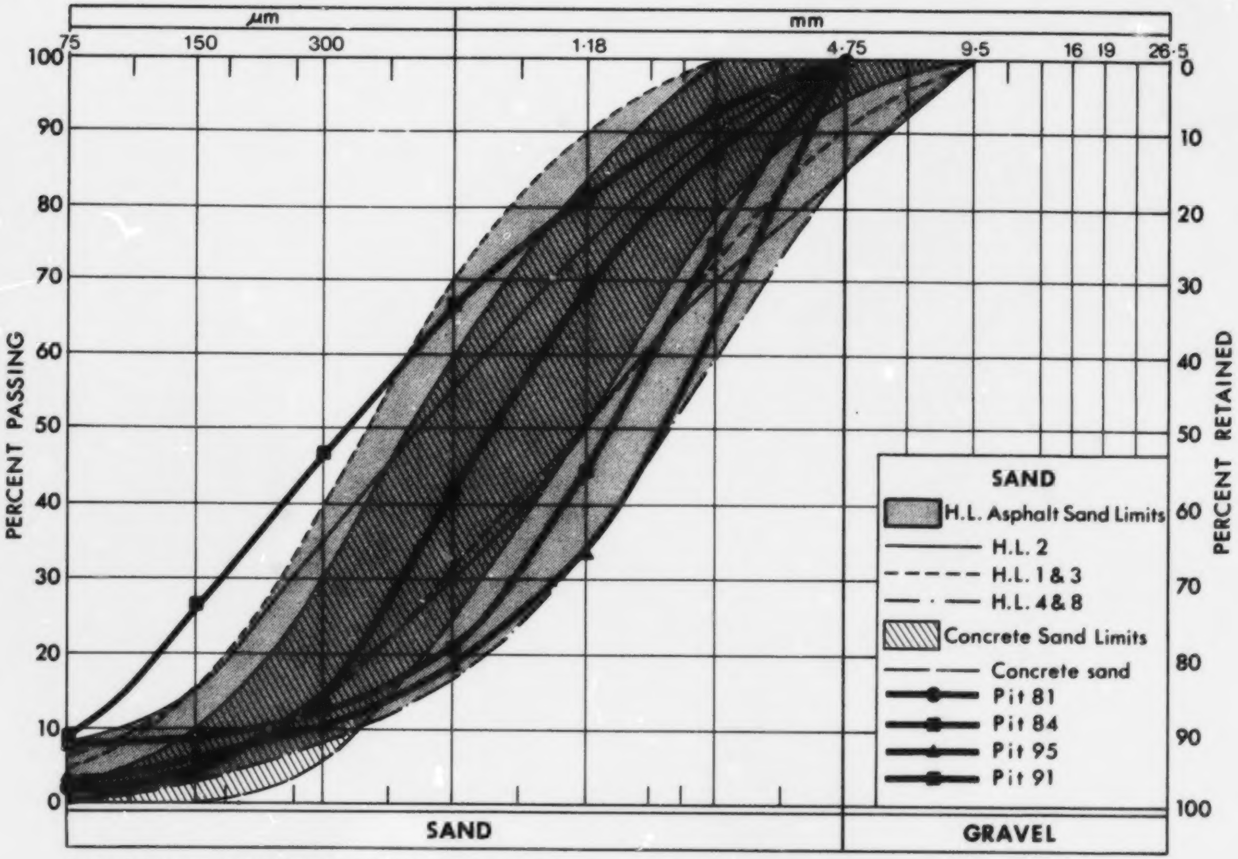


FIGURE 8b: AGGREGATE GRADING CURVES, MANITOUWADGE MAP AREA;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

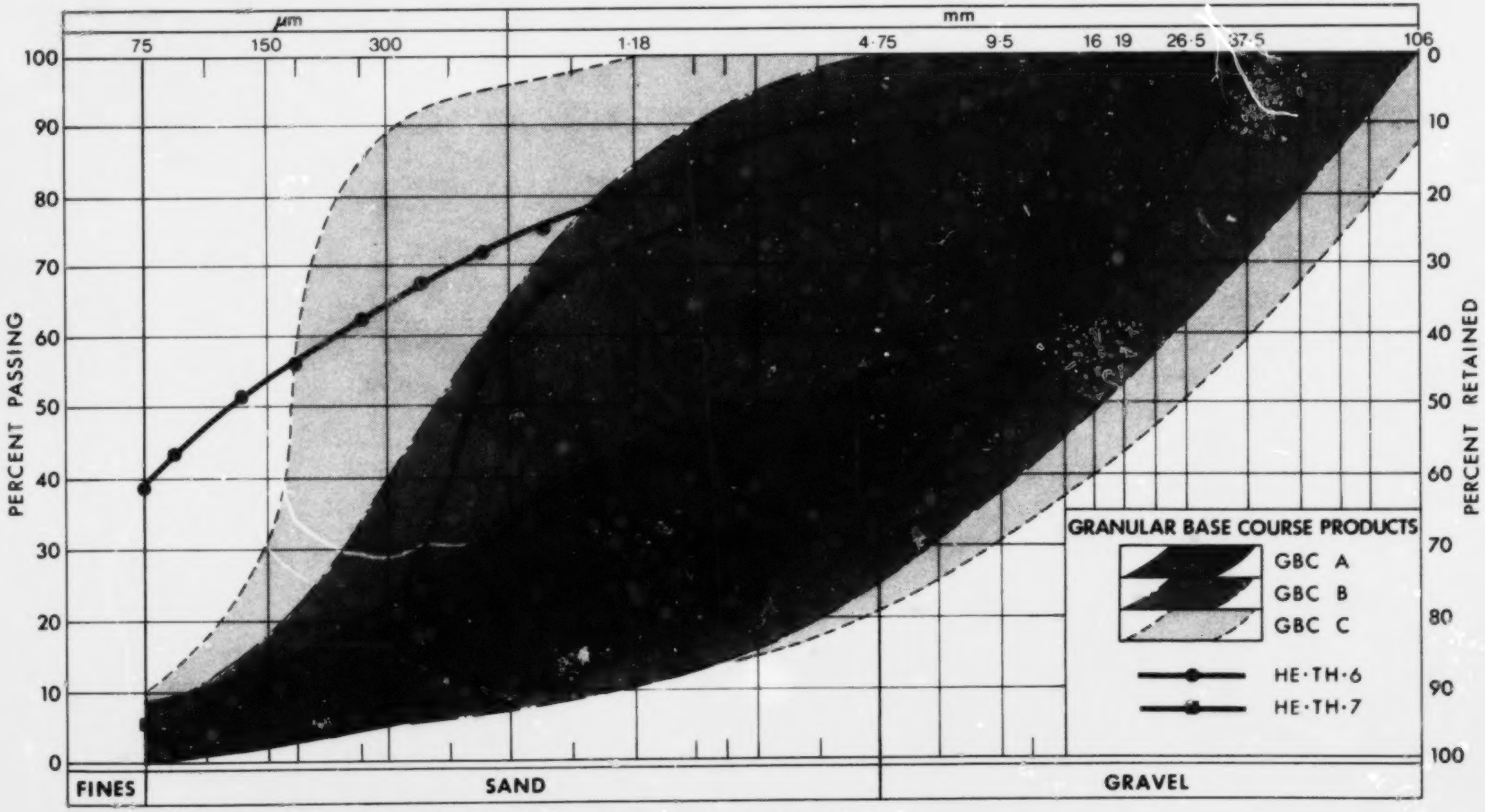


FIGURE 9a AGGREGATE GRADING CURVES, MANITOUWADGE MAP AREA;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

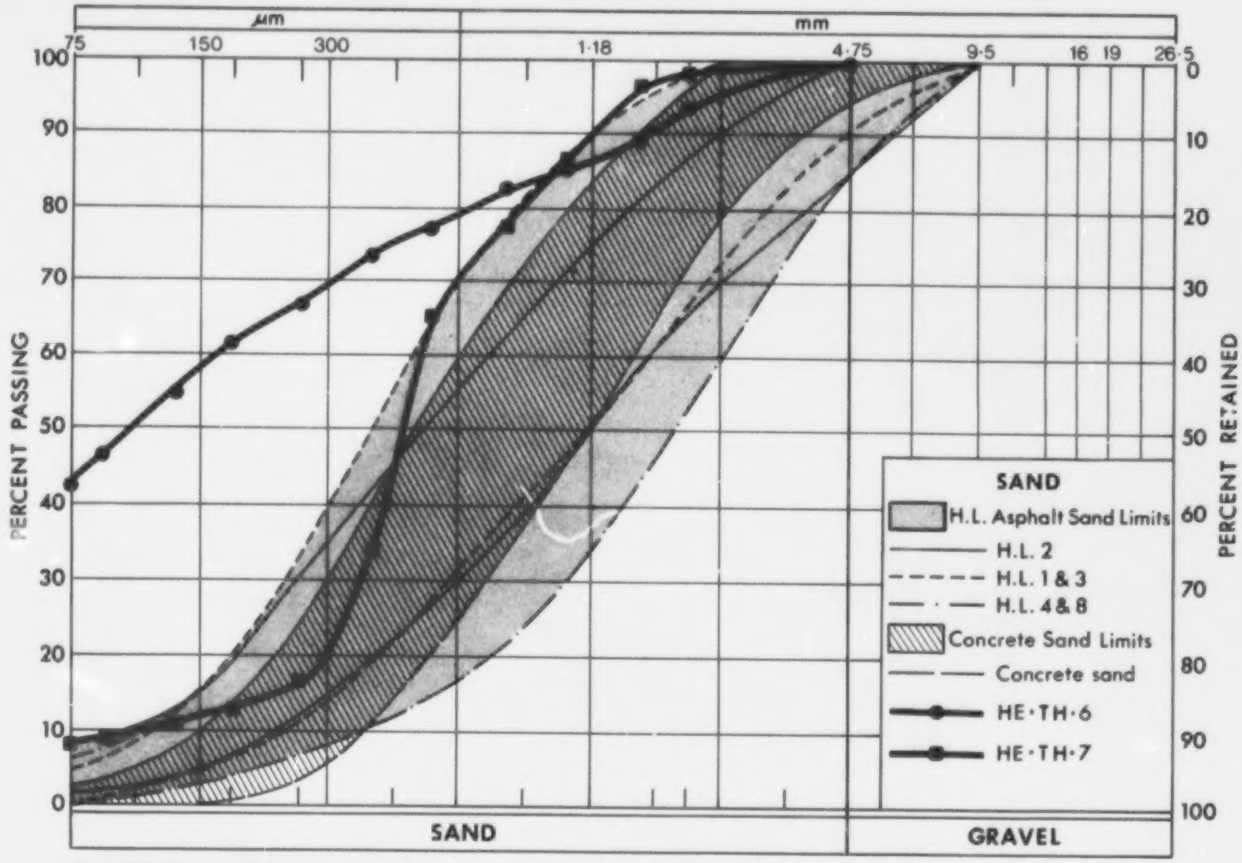


FIGURE 9b: AGGREGATE GRADING CURVES, MANITOUWADGE MAP AREA;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

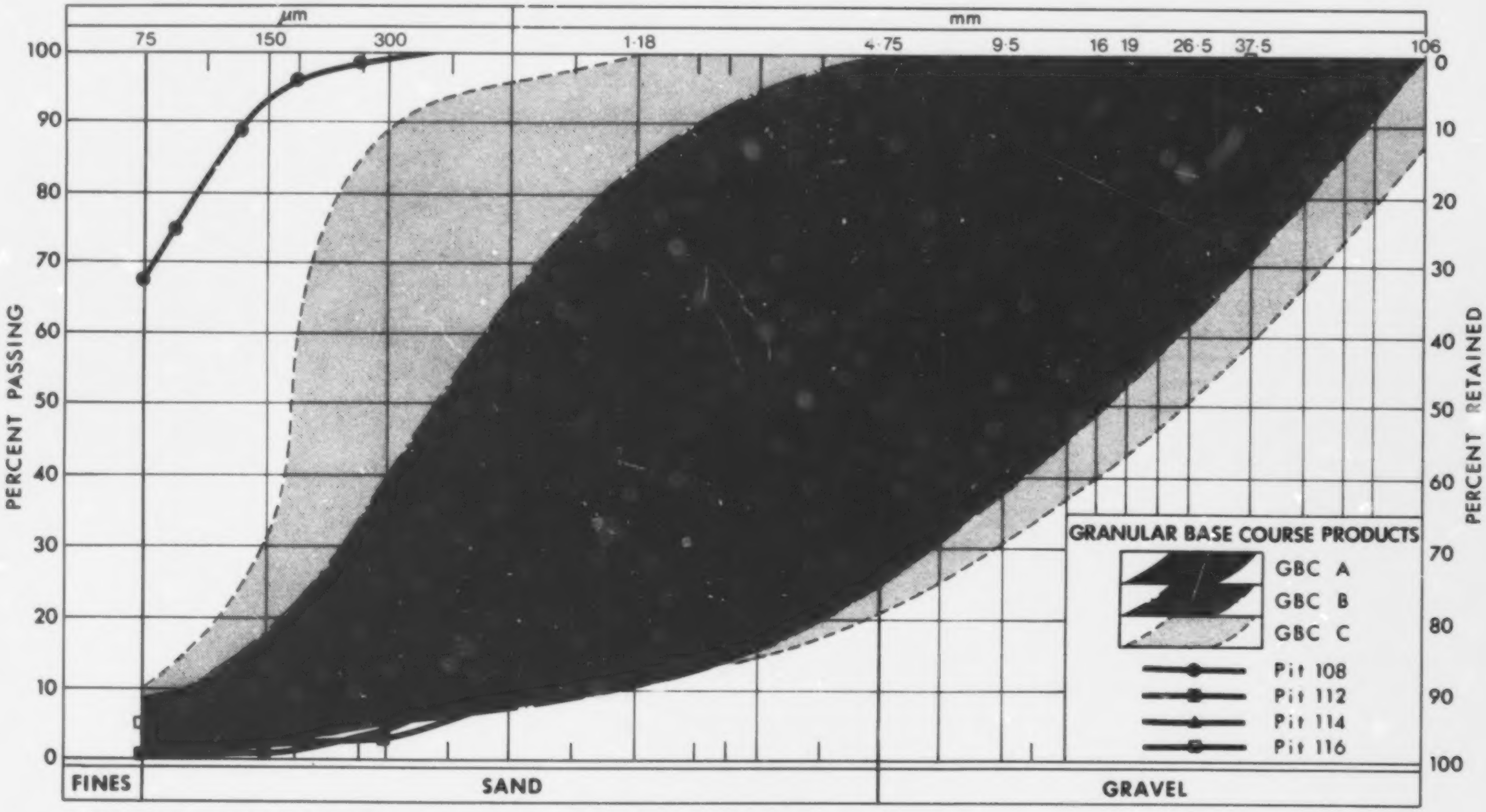


FIGURE 10a: AGGREGATE GRADING CURVES, WHITE RIVER MAP AREA;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

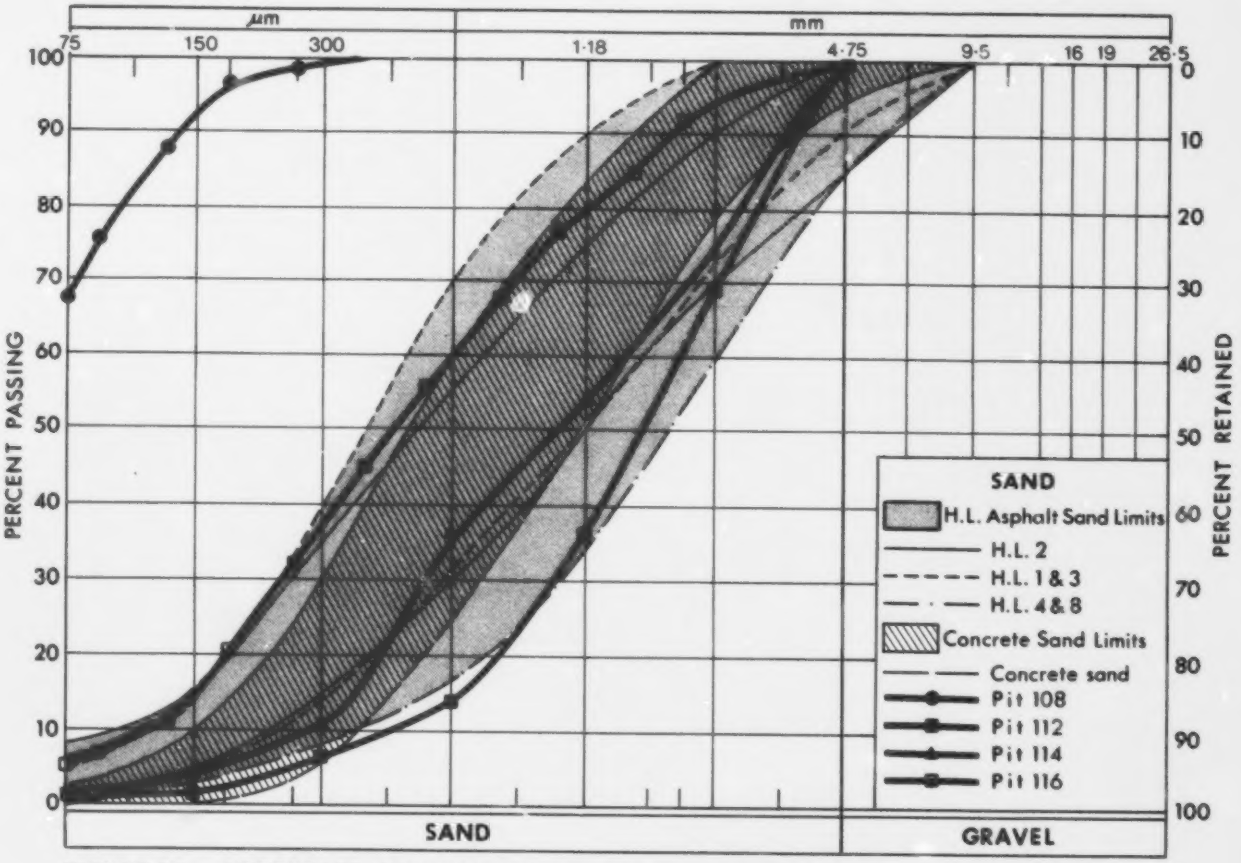


FIGURE 10b: AGGREGATE GRADING CURVES, WHITE RIVER MAP AREA;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

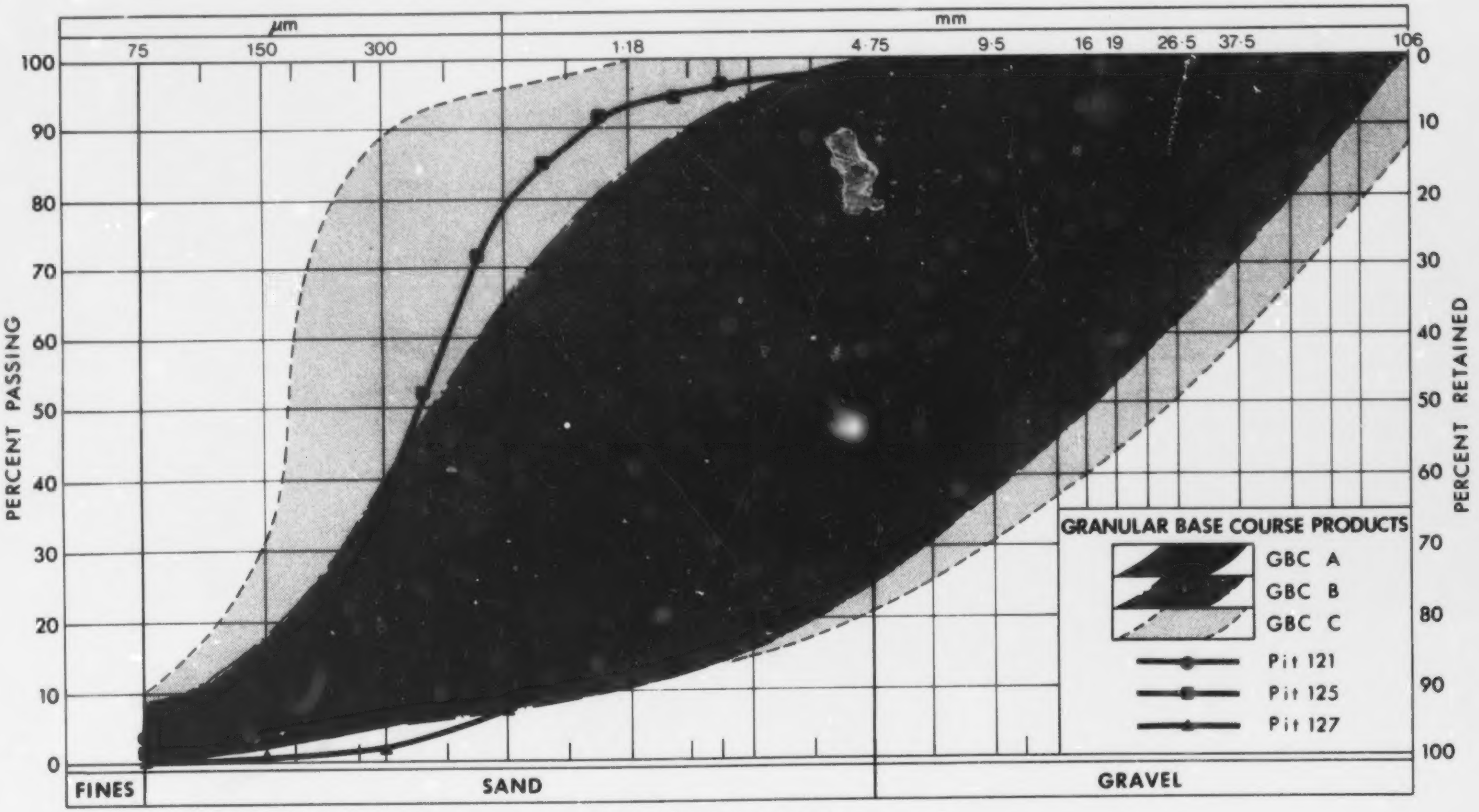


FIGURE 11a: AGGREGATE GRADING CURVES, WHITE RIVER MAP AREA;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly t[illegible]cific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care [illegible] be exercised in extrapolating such information to the rest of the deposit.

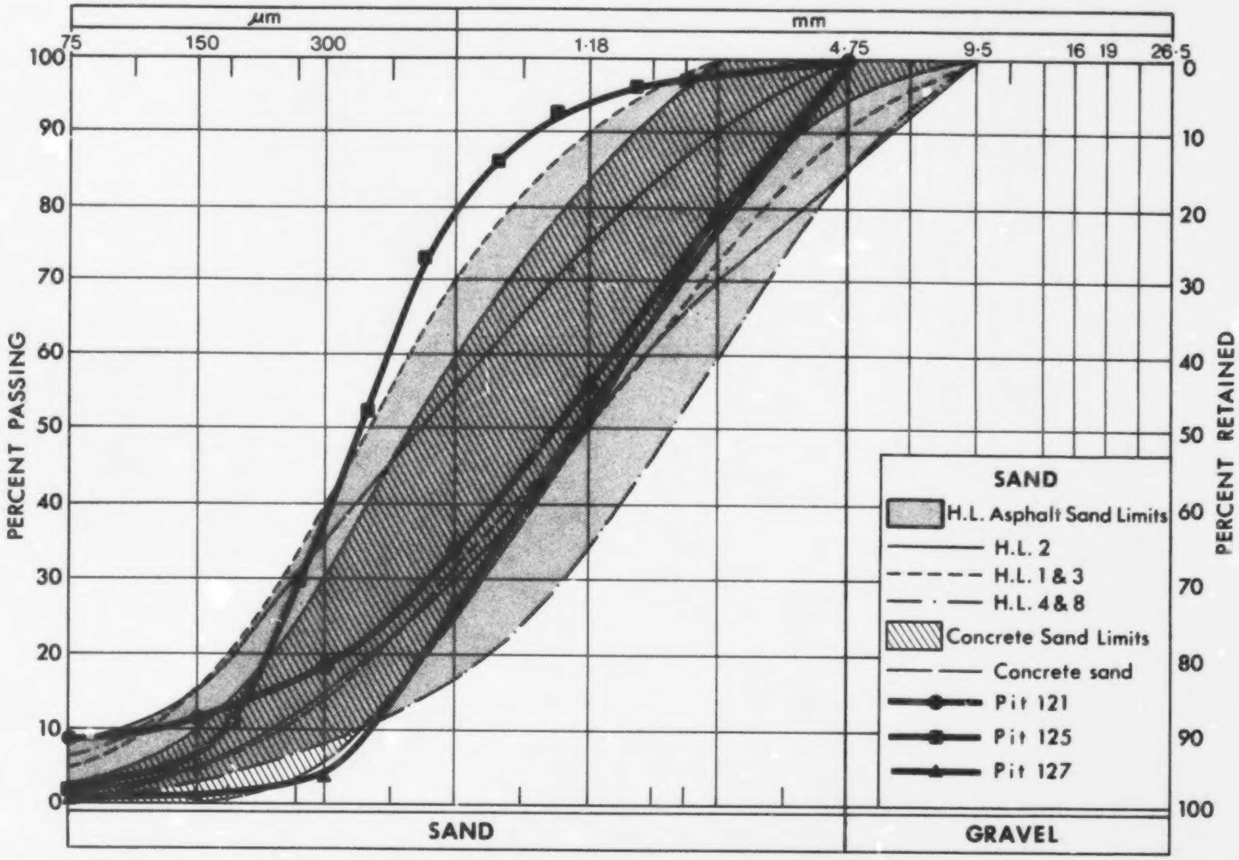


FIGURE 11b: AGGREGATE GRADING CURVES, WHITE RIVER MAP AREA;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

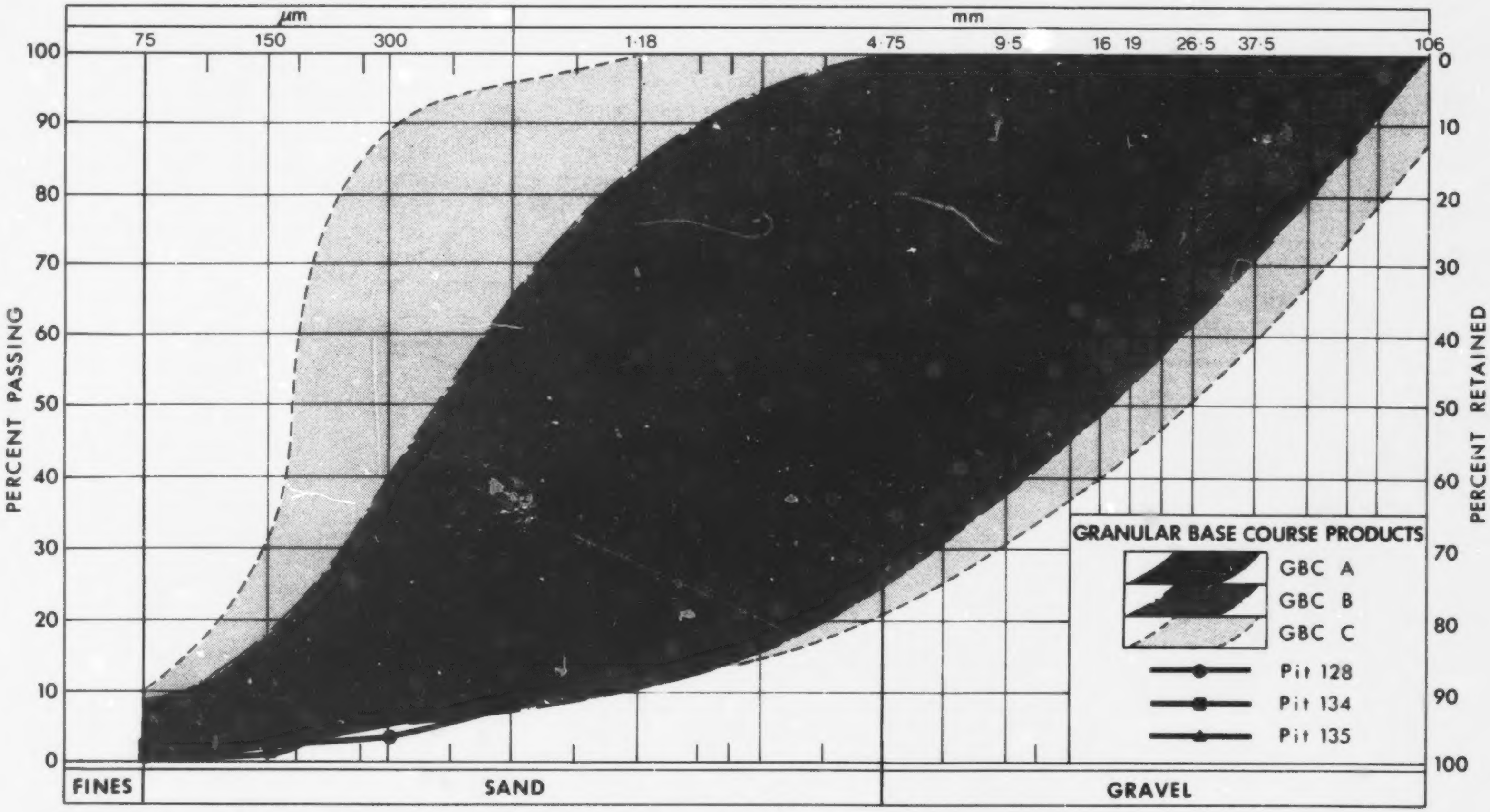


FIGURE 12a: AGGREGATE GRADING CURVES, WHITE RIVER MAP AREA;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

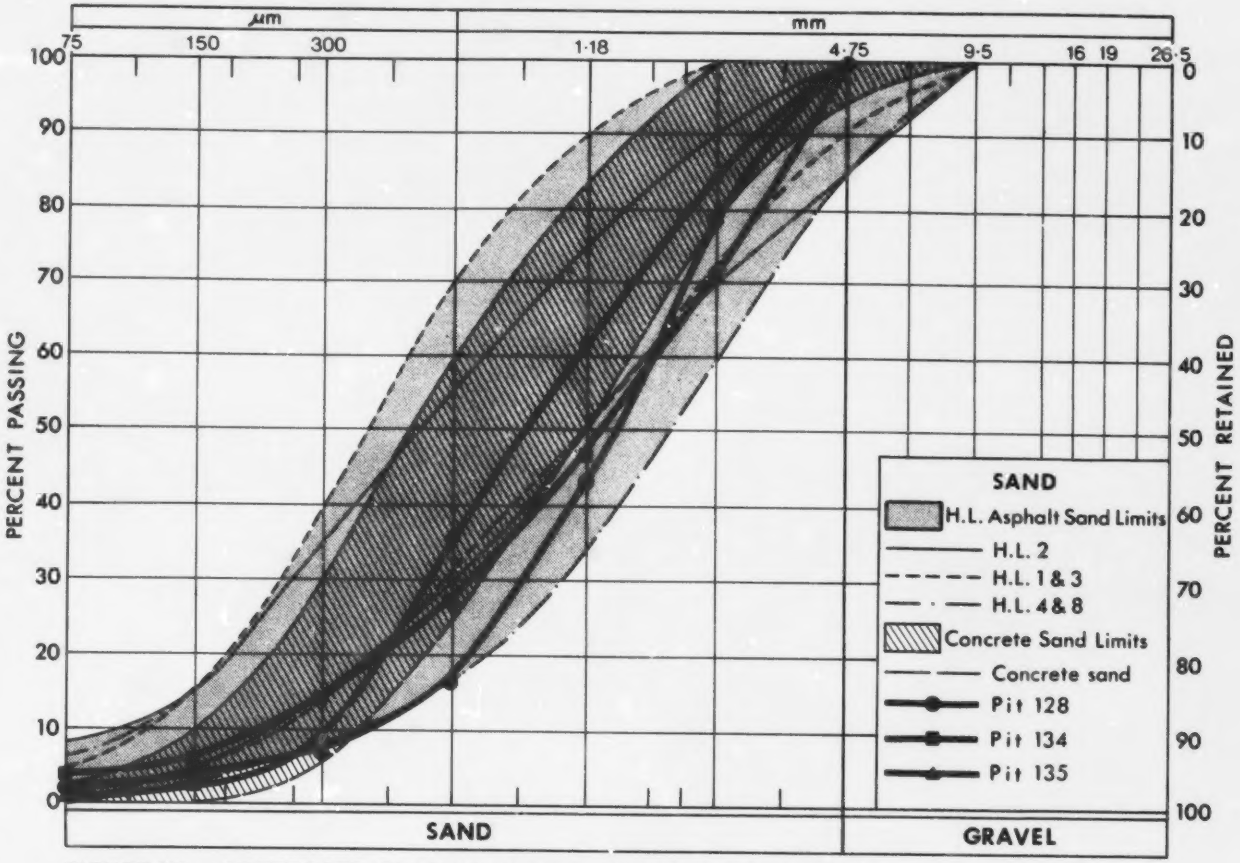


FIGURE 12b: AGGREGATE GRADING CURVES, WHITE RIVER MAP AREA;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

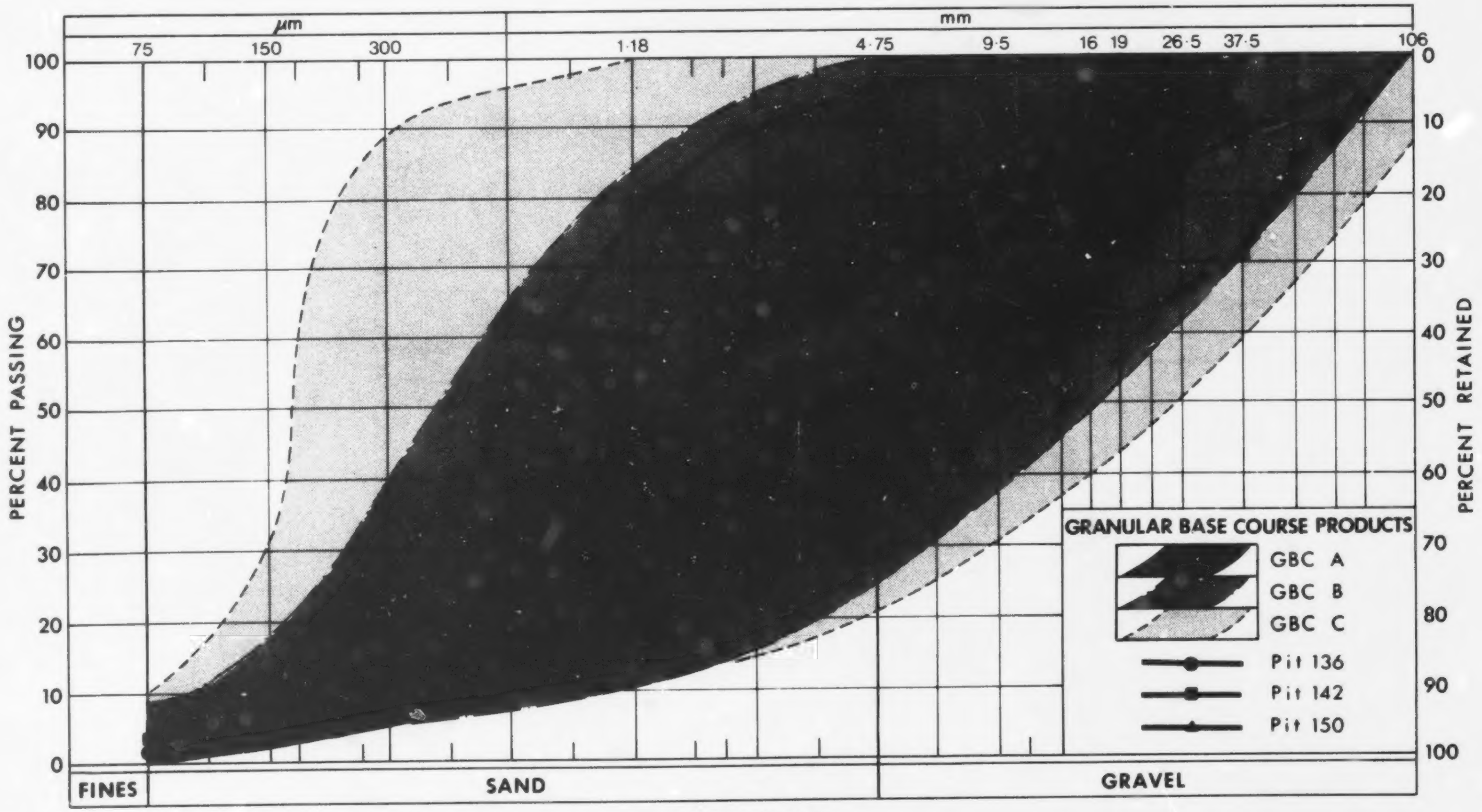


FIGURE 13a: AGGREGATE GRADING CURVES, WHITE RIVER MAP AREA;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

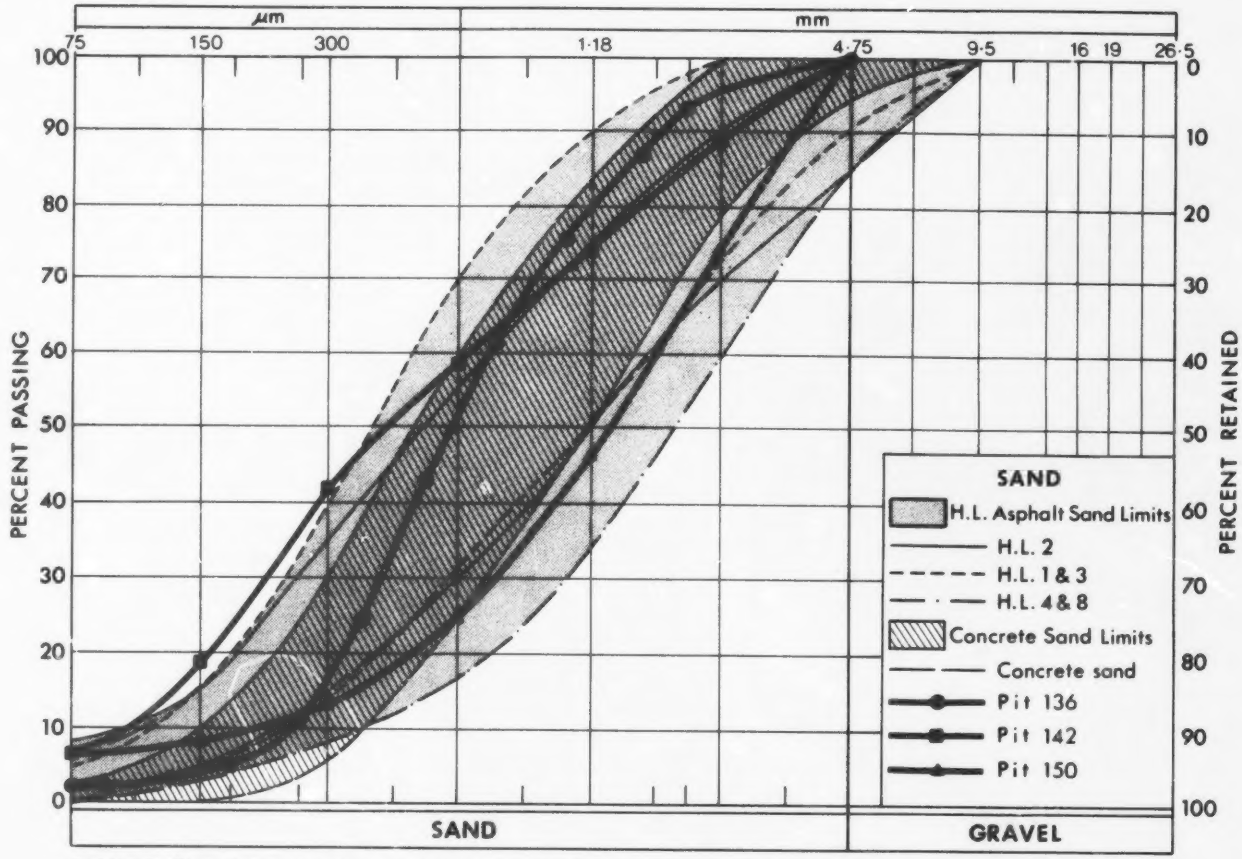


FIGURE 13b: AGGREGATE GRADING CURVES, WHITE RIVER MAP AREA;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

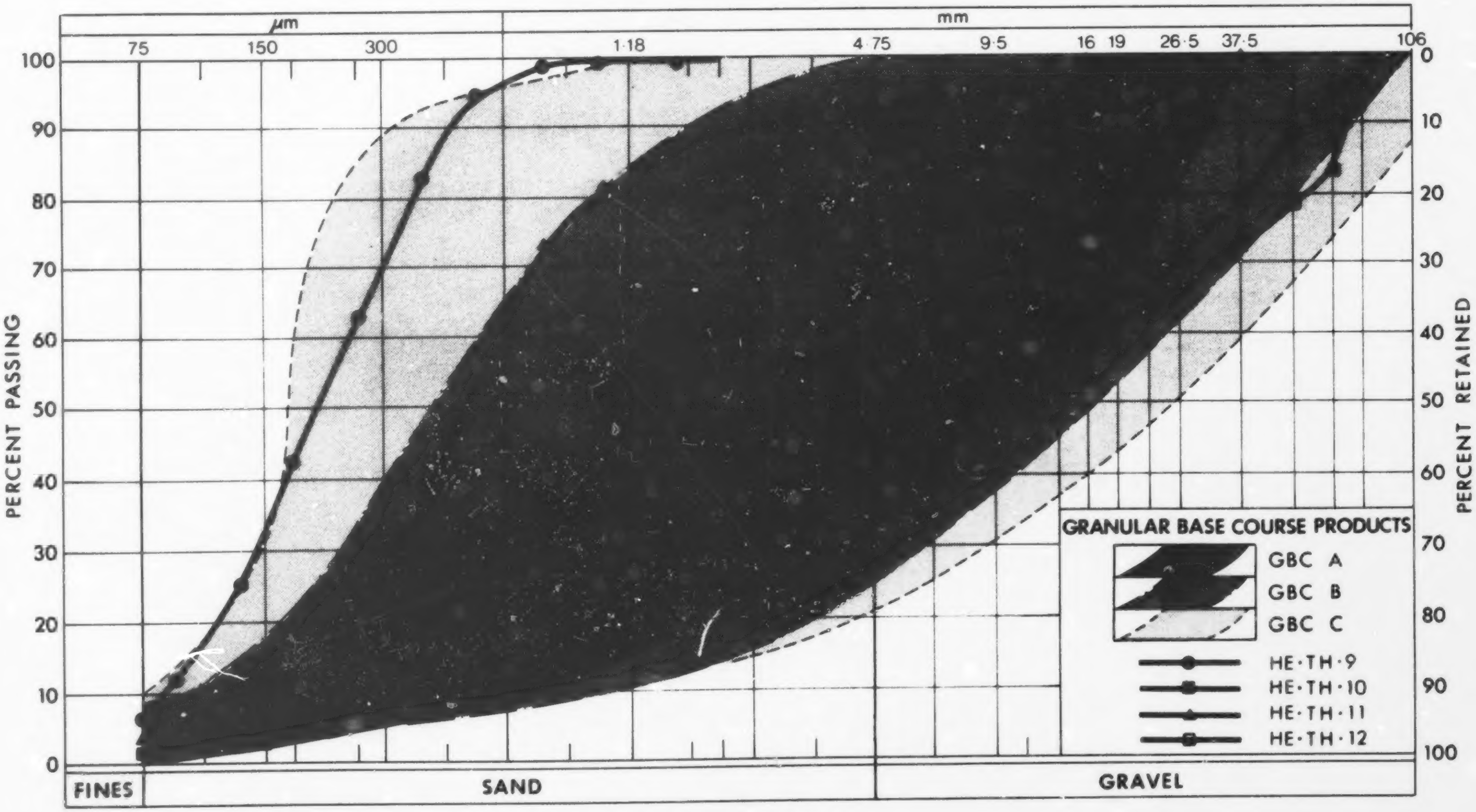


FIGURE 14a: AGGREGATE GRADING CURVES, WHITE RIVER MAP AREA;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

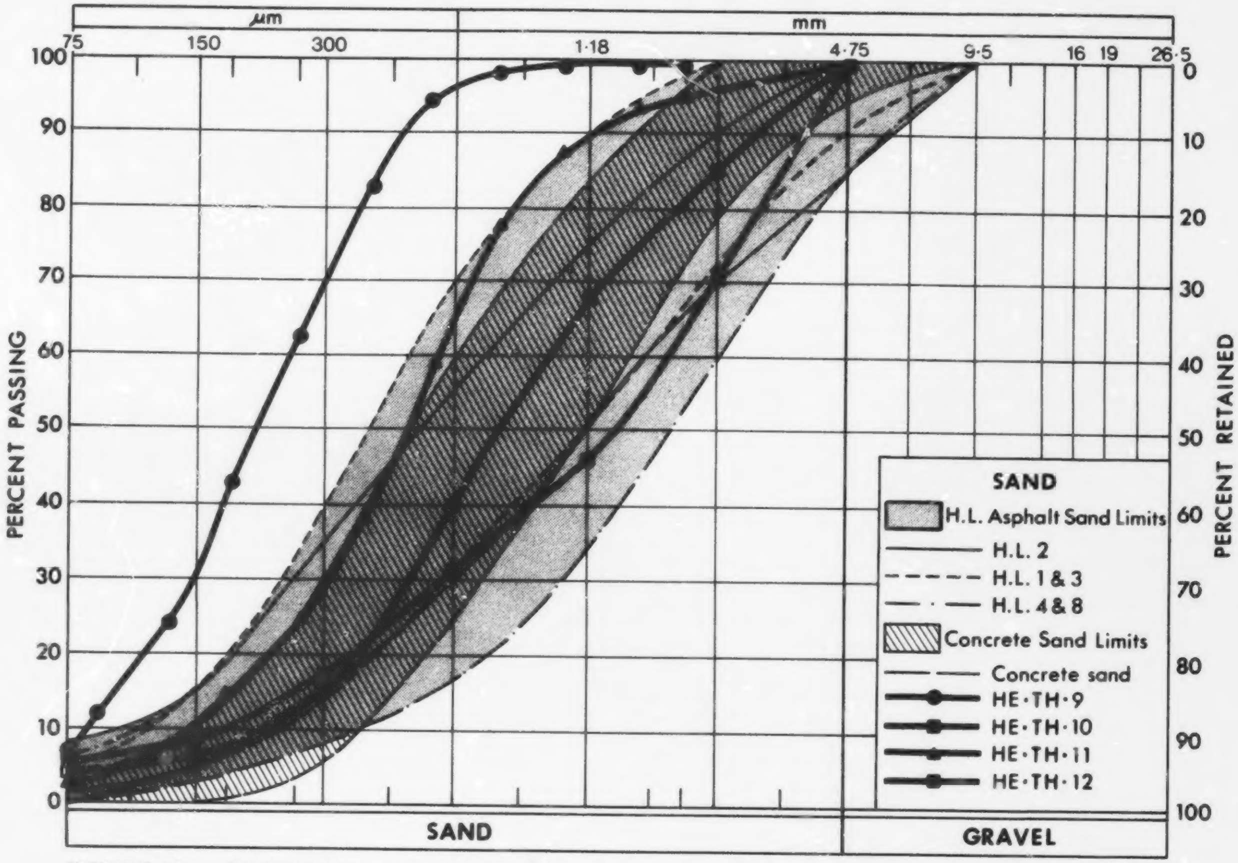


FIGURE 14b: AGGREGATE GRADING CURVES, WHITE RIVER MAP AREA;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

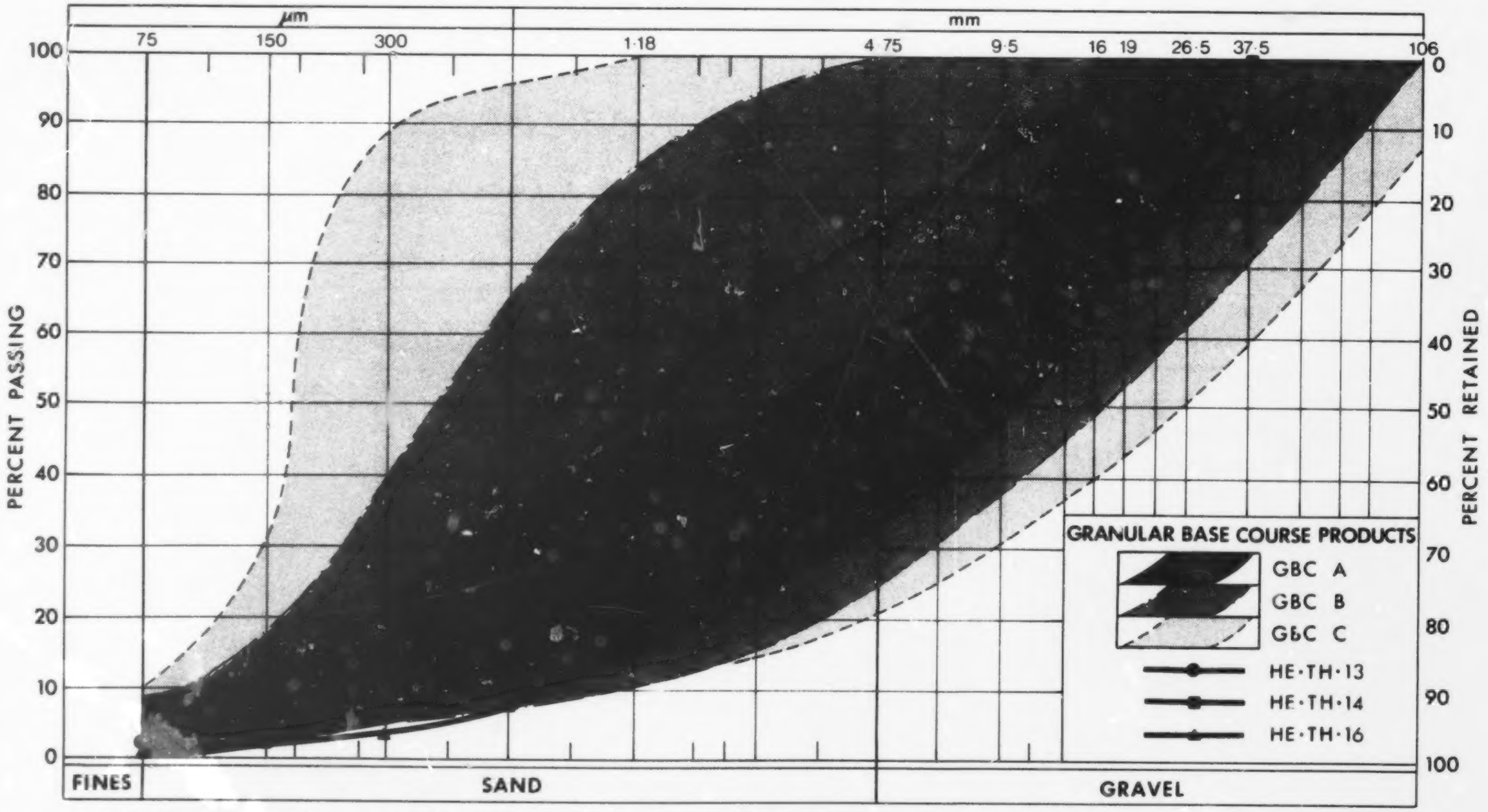


FIGURE 15a: AGGREGATE GRADING CURVES, WHITE RIVER MAP AREA;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

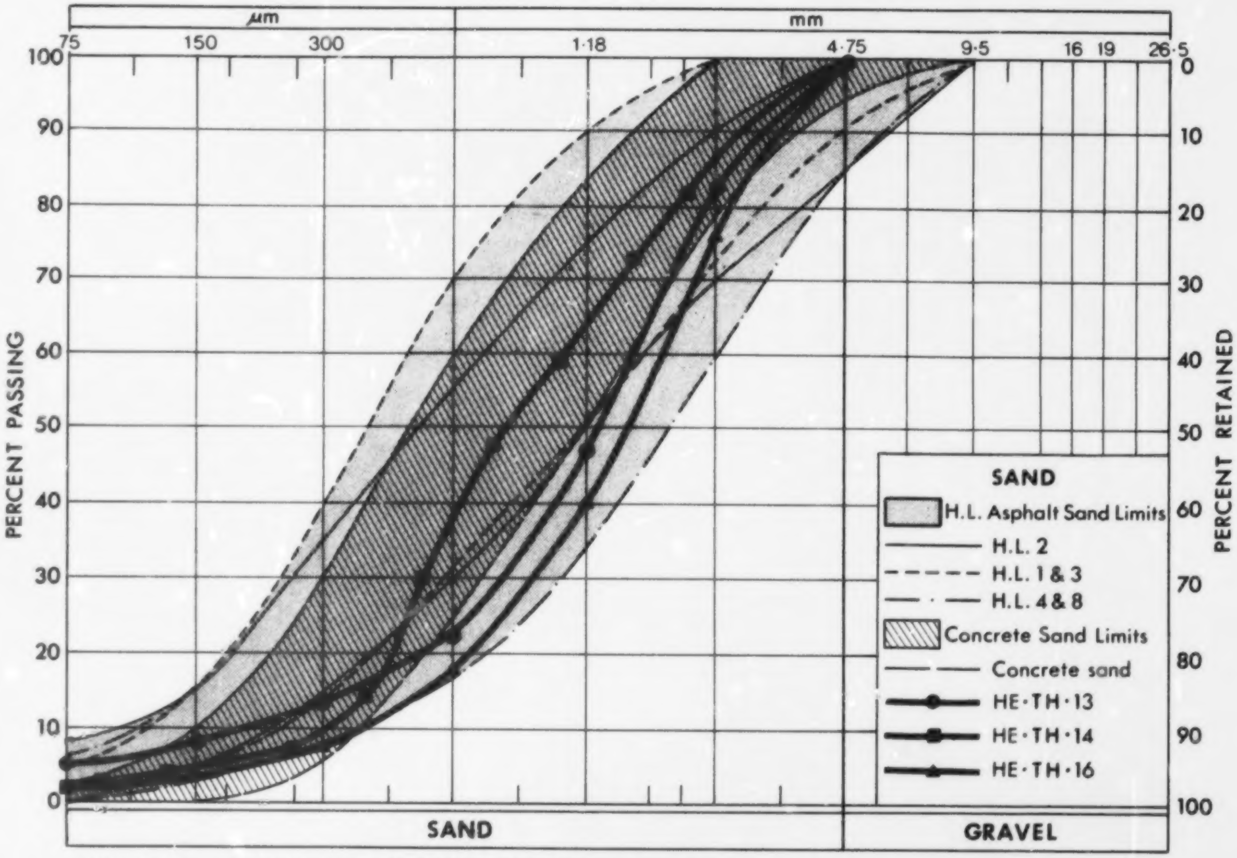


FIGURE 15b: AGGREGATE GRADING CURVES, WHITE RIVER MAP AREA;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

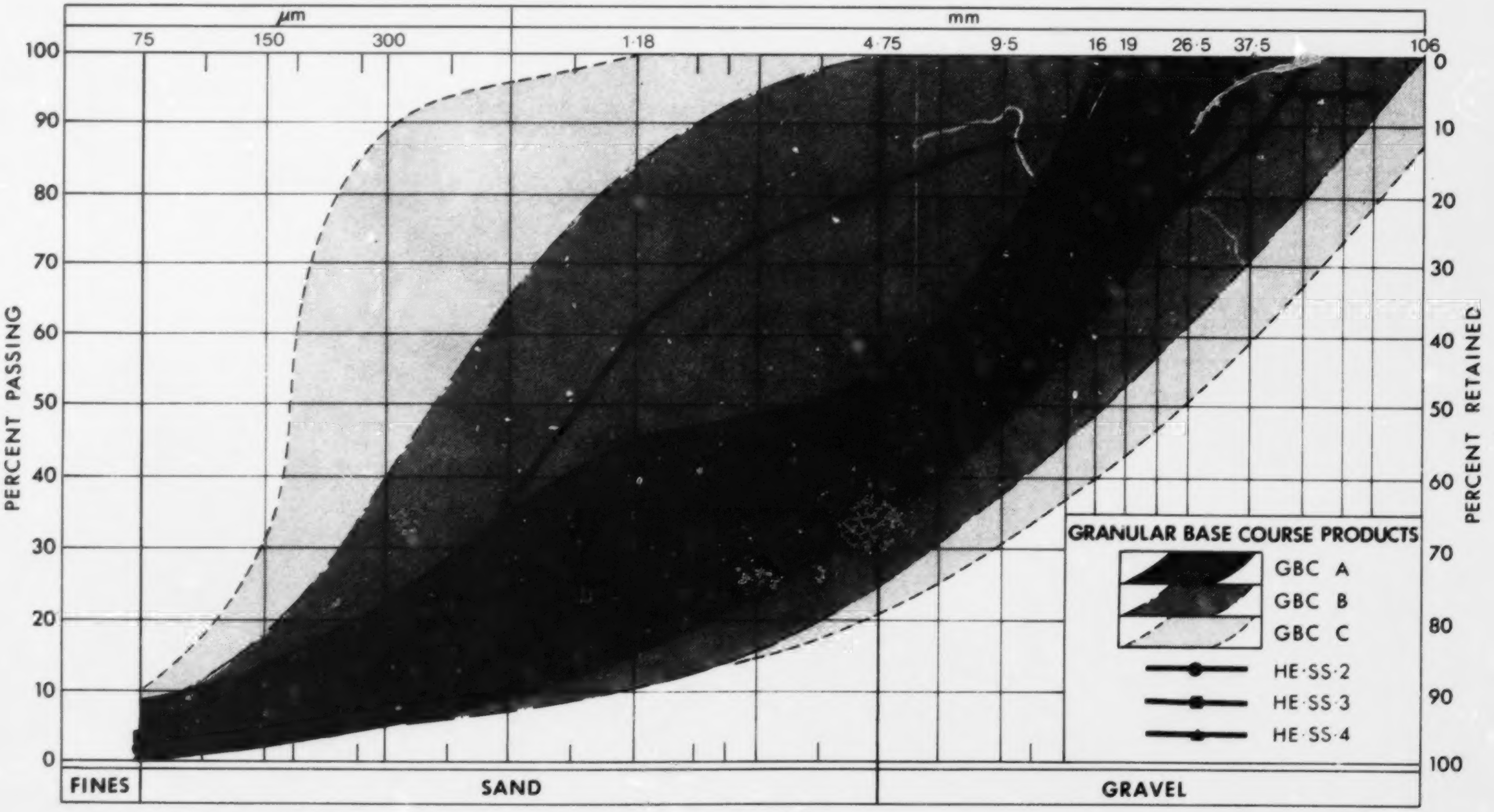


FIGURE 16a: AGGREGATE GRADING CURVES, WHITE RIVER MAP AREA;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

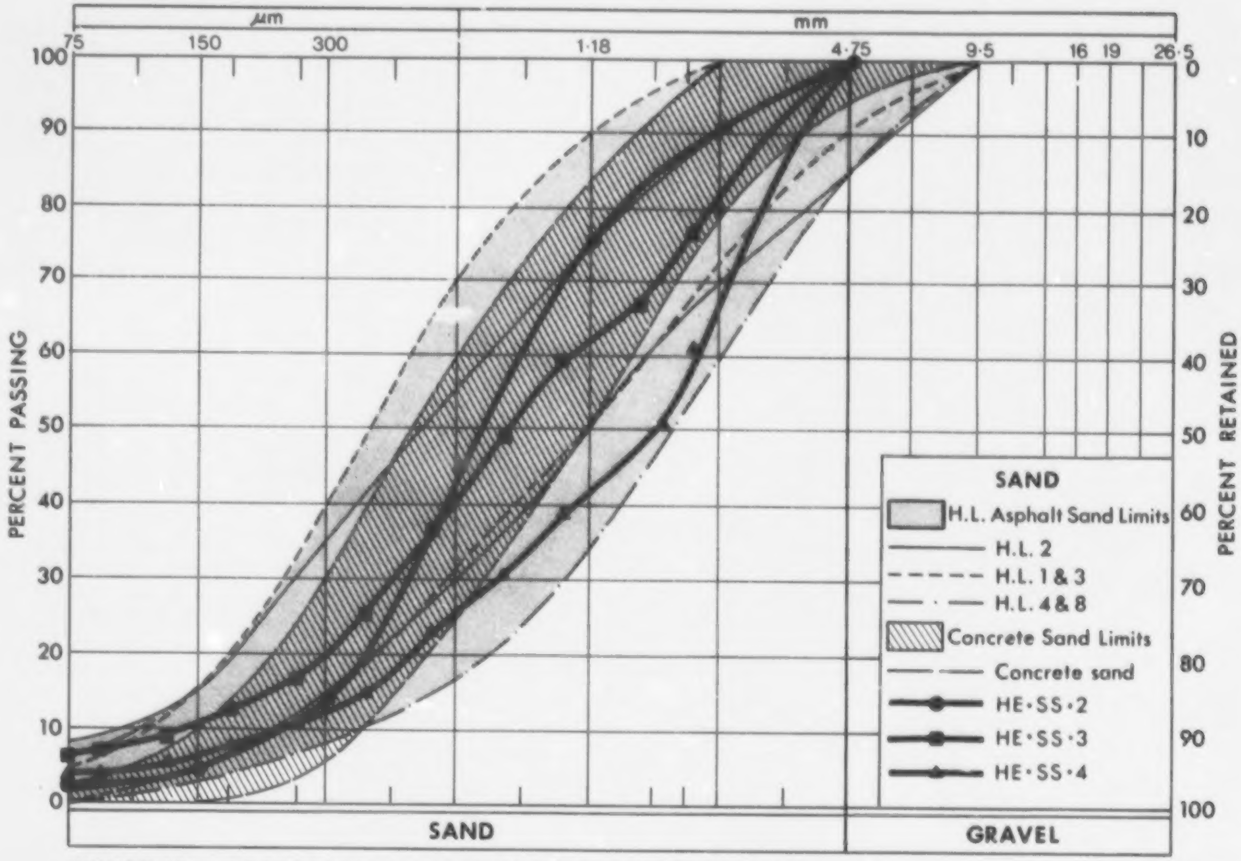


FIGURE 16b: AGGREGATE GRADING CURVES, WHITE RIVER MAP AREA;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

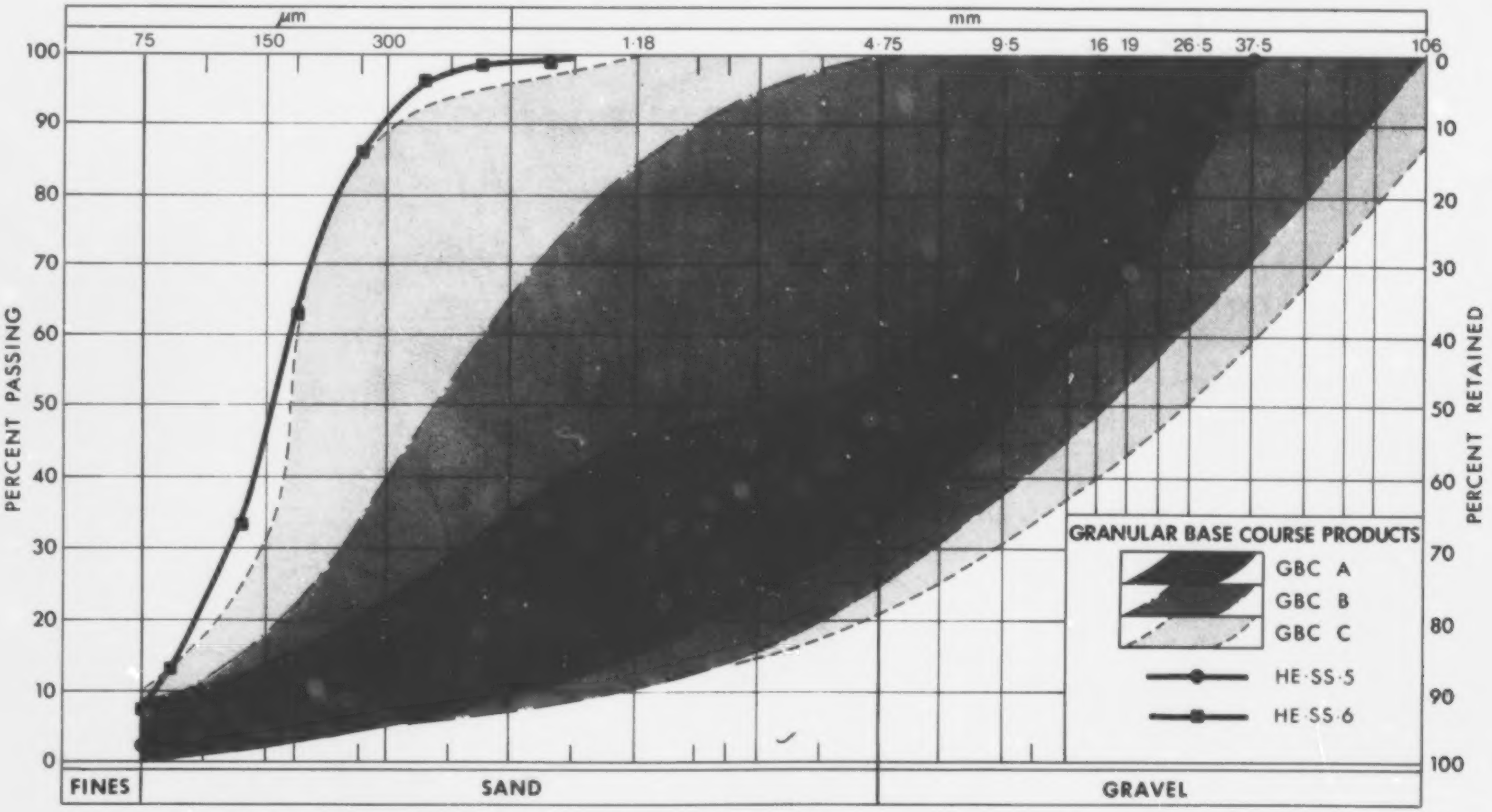


FIGURE 17a: AGGREGATE GRADING CURVES, WHITE RIVER MAP AREA;

Based on analysis of the total aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Form 1010, 1980).

NOTE: Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

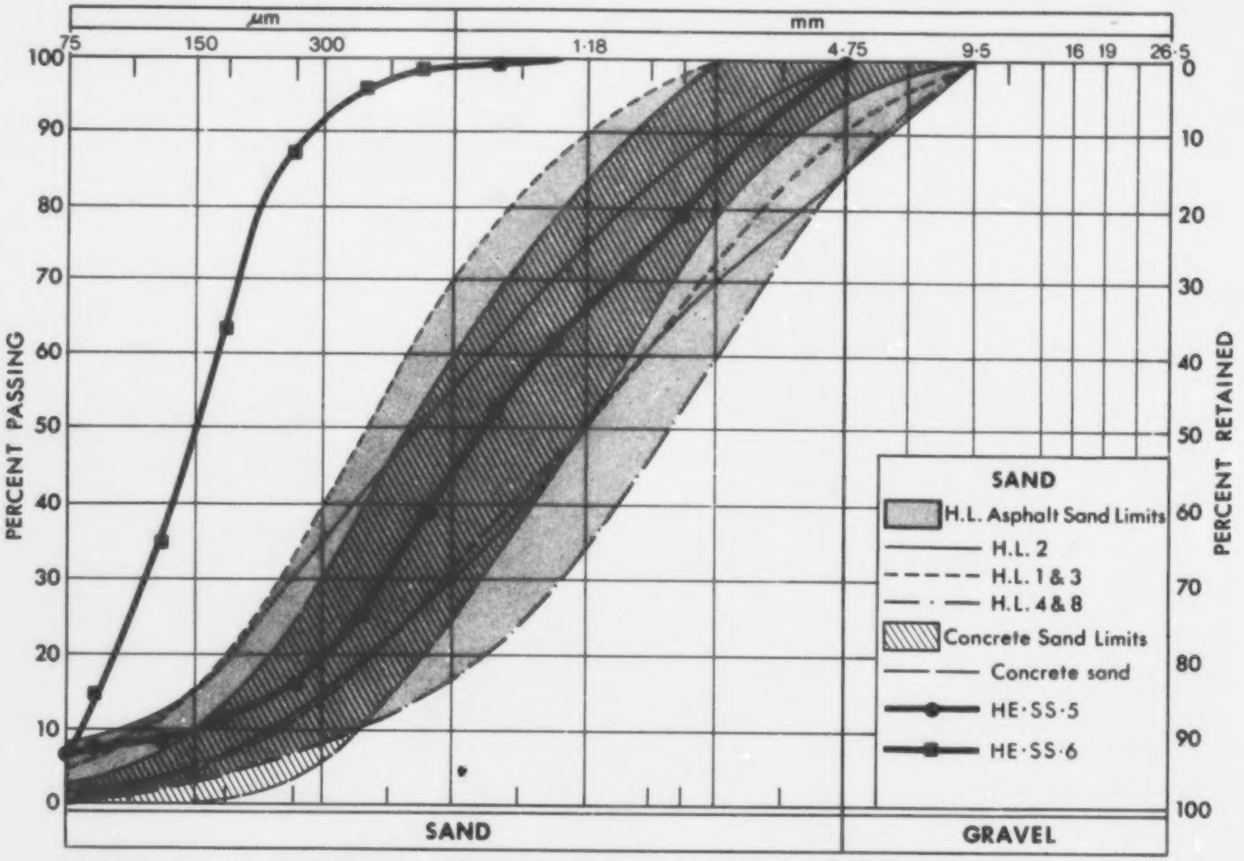


FIGURE 17b: AGGREGATE GRADING CURVES, WHITE RIVER MAP AREA;

Based on analysis of the sand fraction of the aggregate contained in unprocessed samples (gradation envelopes adapted from M.T.C. Forms 1002, 1979 and 1003, 1981).

NOTE:

Information portrayed by grading curves refers strictly to a specific sample taken at the time of field investigation. Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

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Appendix A — Suggested Additional Reading

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Appendix B — Glossary

Abrasion Resistance Tests such as the Los Angeles Abrasion Test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

Absorption Capacity Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

Aggregate Any hard, inert, construction material (sand, gravel, shells, slag, crushed stone or other mineral material) used for mixing in various-sized fragments with a cement or bituminous material to form concrete, mortar, etc., or used alone for road building or other construction. Synonyms include mineral aggregate and granular material.

Alkali-Aggregate Reaction A chemical reaction between the alkalis of portland cement and certain minerals found in rocks used for aggregate. Alkali-aggregate reactions are undesirable because they can cause expansion and cracking of concrete. Although perfectly suitable for building stone and asphalt applications, alkali-reactive aggregates should be avoided for concrete uses.

Blending Required in cases of extreme coarseness, fineness, or other irregularities in the gradation of unprocessed aggregate. Blending is done with approved sand-sized aggregate in order to satisfy the gradation requirements of the material.

Clast An individual constituent, grain, or fragment of a sediment or rock, produced by the mechanical weathering of a larger rock mass. Synonyms include particle and fragment.

Crushable Aggregate Unprocessed gravel containing a minimum of 35 percent coarse aggregate larger than the No. 4 sieve (4.75 mm) as well as a minimum of 20 percent greater than the 26.5 mm sieve.

Deleterious Lithology A general term used to designate those rock types which are chemically or physically unsuited for use as construction or road-building aggregates. Such lithologies as chert, shale, siltstone, and sandstone may deteriorate rapidly when exposed to traffic and other environmental conditions. Similarly, highly weathered, very porous and friable rock can restrict the quality of the aggregate.

Dolostone A carbonate sedimentary rock consisting chiefly of the mineral dolomite and containing relatively little calcite (dolostone is also known as dolomite).

Drift A general term for all unconsolidated rock debris transported from one place and deposited in another; distinguished from underlying bedrock. In North America, glacial activity has been the dominant mode of transport and deposition of drift. Synonyms include overburden and surficial deposit.

Drumlin A low, smoothly rounded, elongated hill, mound, or ridge composed of glacial materials. These landforms were deposited beneath an advancing ice sheet, and were shaped by its flow.

Eolian Pertaining to the wind, especially with respect to landforms whose constituents were tansported and deposited by wind activity. Sand dunes are an example of an eolian landform.

Fines A general term used to describe the size fraction of an aggregate which passes (is finer than) the No. 200 mesh screen (0.075 mm). Also described informally as "dirt", these particles are in the silt and clay size range.

Gneiss A coarse-textured metamorphic rock with the minerals arranged in parallel streaks or bands. Gneiss is relatively rich in feldspar. Other common minerals found in this rock include quartz, mica, amphibole and garnet.

Gradation The proportion of material of each particle size, or the frequency distribution of the various sizes which constitute a sediment. The strength, durability, permeability and stability of an aggregate depend to a great extent on its gradation. The size limits for different particles are as follows:

Boulders	more than 200 mm
Cobbles	75-200 mm
Coarse Gravel	26.5-75 mm
Fine Gravel	4.75-26.5 mm
Coarse Sand	2-4.75 mm
Medium Sand	0.425-2 mm
Fine Sand	0.075-0.425 mm
Silt, Clay	less than 0.075 mm

Granite Is a coarse-grained light coloured rock that ordinarily has an even texture and is composed of quartz, and feldspar with either mica, hornblende or both.

Granular Base Course Components of the pavement structure of a road, which are placed on the subgrade and are designed to provide strength, stability, and drainage, as well as support for surfacing materials. Several types have been defined: Granular Base Course A consists of crushed and processed aggregate and has relatively stringent quality standards in comparison to Granular Base Course B and C which are usually pit-run or other unprocessed aggregate.

Hot-Laid (or Asphaltic) Aggregate Bituminous, cemented aggregates used in the construction of pavements either as surface or bearing course (H.L. 1, 3, and 4), or as binder course (H.L. 2, 6, and 8) used to bind the surface course to the underlying granular base course.

Lithology The description of rocks on the basis of such characteristics as colour, structure, mineral composition, and grain size. Generally, the description of the physical character of a rock.

Magnesium Sulphate Soundness Test This test is designed to simulate the action of freezing and thawing on aggregates. Those aggregates which are susceptible will usually break down and give high losses in this test.

Meltwater Channel A drainage way, often terraced, produced by water flowing away from a melting glacier margin.

Petrographic Examination An aggregate quality test based on known field performance of various rock types. The test result is a Petrographic Number (P.N.). The higher the P.N. the lower the quality of aggregate.

Pleistocene An epoch of the recent geological past including the time from approximately 2 million years ago to 7000 years ago. Much of the Pleistocene was characterized by extensive glacial activity and is popularly referred to as the "Great Ice Age".

Possible Resource Reserve estimates based largely on broad knowledge of the geologic character of the deposit and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition for which there are reasonable geological indications.

Precambrian The earliest subdivision of earth history extending from the consolidation of the earth's crust to the beginning of the Phanerozoic Era.

Soundness The ability of the components of an aggregate to withstand the effects of various weathering processes and agents. Unsound lithologies are subject to disintegration caused by the expansion of absorbed solutions. This may seriously impair the performance of road-building and construction aggregates.

Till Unsorted and unstratified rock debris, deposited directly by glaciers, and ranging in size from clay to large boulders.

Wisconsinan Pertaining to the last glacial stage of the Pleistocene Epoch in North America. It began approximately 100 000 years ago and ended approximately 7000 years ago. The glacial deposits and landforms of Ontario are predominantly the result of glacial activity during the Wisconsinan Stage.

Appendix C — Geology of Sand and Gravel Deposits

The type, distribution, and extent of sand and gravel deposits in Ontario are the result of extensive glacial and glacially influenced activity in Wisconsinan time during the Pleistocene Epoch, approximately 100 000 to 7000 years ago. The deposit types reflect the different depositional environments that existed during the melting and retreat of the continental ice masses, and they can readily be differentiated on the basis of their morphology, structure, and texture. The deposit types are described below.

GLACIOFLUVIAL DEPOSITS

These deposits can be divided into two broad categories: those that were formed in contact with (or in close proximity to) glacial ice, and those that were deposited by meltwaters carrying materials beyond the ice margin.

Ice-Contact Terraces (ICT) These are glaciofluvial features deposited between the glacial margin and a confining topographic high, such as the side of a valley. The structure of the deposits may be similar to that of outwash deposits, but in most cases the sorting and grading of the material is more variable and the bedding is discontinuous due to extensive slumping. The probability of locating large amounts of crushable aggregate is moderate, and extraction may be expensive due to the variability of the deposits both in terms of quality and grain size distribution.

Kames (K) Kames are defined as mounds of poorly sorted sand and gravel deposited by meltwater in depressions or fissures on the ice surface or at its margin. During glacial retreat, the melting of supporting ice causes collapse of the deposits, producing internal structures characterized by bedding discontinuities. The deposits consist mainly of irregularly bedded and crossbedded, poorly sorted sand and gravel. The present forms of the deposits include single mounds, linear ridges (crevasse fillings) or complex groups of landforms. The latter are occasionally described as "undifferentiated ice-contact stratified drift" (IC) when detailed subsurface information is unavailable. Since kames commonly contain large amounts of fine- grained material and are characterized by considerable variability, there is generally a low to moderate probability of discovering large amounts of good quality, crushable aggregate. Extractive problems encountered in these deposits are mainly the excessive variability of the aggregate and the presence of excess fine (silt- and clay-sized particles).

Eskers (E) Eskers are narrow, sinuous ridges of sand and gravel deposited by meltwaters flowing in tunnels within or at the base of glaciers, or in channels on the ice surface. Eskers vary greatly in size. Many, though not all eskers consist of a central core of poorly sorted and stratified gravel characterized by a wide range in grain size. The core material is often draped on its flanks by better sorted and stratified sand and gravel. The deposits have a high probability of containing a large proportion of crushable aggregate, and since they are generally built above the surrounding ground surface, are convenient extraction sites. For these reasons esker deposits have been traditional aggregate sources throughout Ontario, and are significant components of the total resources of many areas.

Some planning constraints and opportunities are inherent in the nature of the deposits. Because of their linear nature, the deposits commonly extend across several property boundaries leading to unorganized extractive development at numerous small pits. On the other hand, because of their form, eskers can be easily and inexpensively extracted and are amenable to rehabilitation and sequential land use.

Undifferentiated Ice-Contact Stratified Drift (IC) This designation may include deposits from several ice-contact, depositional environments which usually form extensive, complex landforms. It is not feasible to identify individual areas of coarse-grained material within such deposits due to their lack of continuity and grain size variability. They are given a qualitative rating based on existing pit and other subsurface data.

Outwash (OW) Outwash deposits consist of sand and gravel laid down by meltwaters beyond the margin of the glacier. The deposits occur as sheets or as terraced valley fills (valley trains) and may be very large in extent and thickness. Well developed outwash deposits have good horizontal bedding and are uniform in grain size distribution. Outwash deposited near the glacier's margin is much more variable in texture and structure. The probability of locating useful crushable aggregates in outwash deposits is moderate to high depending on how much information on size, distribution and thickness is available.

Alluvium (AL) Alluvium is a general term for clay, silt, sand, gravel, or similar unconsolidated material deposited during postglacial time by a stream as sorted or semi-sorted sediment, on its bed or on its floodplain. The probability of locating large amounts of crushable aggregate in alluvial deposits is low, and it has generally low value due to the presence of excess silt- and clay-sized material. There are no large postglacial alluvium deposits in Ontario.

GLACIOLACUSTRINE DEPOSITS

Glaciolacustrine Beach Deposits (LB) These are relatively narrow, linear features formed by wave action at the shores of glacial lakes that existed at various times during the deglaciation of Ontario. Well developed lacustrine beaches are usually less than 20 feet (6 m) thick. The aggregate is well sorted and stratified and sand-sized material commonly predominates. The composition and size distribution of the deposit depends on the nature of the underlying material. The probability of obtaining crushable aggregate is high when the material is developed from coarse-grained materials such as a stony till, and low when developed from fine-grained materials. Beaches are relatively narrow, linear deposits, so that extractive operations are often numerous and extensive.

Glaciolacustrine Deltas (LD) These features were formed where streams or rivers of glacial meltwater flowed into lakes and deposited their suspended sediment. In Ontario such deposits tend to consist mainly of sand and abundant silt. However, in near-ice and ice-contact positions, coarse material may be present.

Glaciolacustrine Plain (LP) The nearly level surface marking the floor of an extinct glacial lake. The sediments which form the plain are predominantly fine to medium sand, silt, and clay, and were deposited in relatively deep water. Lacustrine deposits are generally of low value as aggregate sources due to their fine grain size and lack of crushable material. In some aggregate-poor areas, lacustrine deposits may constitute valuable sources of fill and some granular base course aggregate.

GLACIAL DEPOSITS

End Moraines (EM) These are belts of glacial drift deposited at, and parallel to, glacier margins. They commonly consist of ice-contact stratified drift and in such instances are usually called kame moraines. Kame moraines commonly result from deposition between two glacial lobes (interlobate moraines). The probability of locating aggregates within such features is moderate to low. Exploration and development costs are high. Moraines may be very large and contain vast aggregate resources, but the location of the best areas within the moraine is usually poorly defined.

EOLIAN DEPOSITS

Windblown Deposits (WD) Windblown deposits are those formed by the transport and deposition of sand by winds. The form of the deposits ranges from extensive, thin layers to well developed linear and crescentic ridges known as dunes. Most windblown deposits in Ontario are derived from, and deposited on, pre-existing lacustrine sand plain deposits. Windblown sediments are almost invariably composed of fine to coarse sand and are usually well sorted. The probability of locating crushable aggregate in windblown deposits is very low.

Appendix D — Aggregate Quality Test Data

Four types of aggregate quality tests (Table 6) have been performed on selected samples from the project area. The results of these tests (Table 7) along with a description and the specification limits for each test are included in this appendix. Although a specific sample meets or does not meet the specification limits for a certain product, it may or may not be acceptable for that use based on field performance. Additional quality tests other than the four major tests listed in this appendix can be used to determine the suitability of an aggregate. The above four types of tests were performed by the Soils and Aggregate Section, Engineering Materials Office, Ontario Ministry of Transportation and Communications.

ABRASION RESISTANCE

Tests such as the Los Angeles Abrasion Test are used to measure the ability of aggregate to resist crushing and pulverizing under conditions similar to those encountered in processing and use. Measuring resistance is an important component in the evaluation of the quality and prospective uses of aggregate. Hard, durable material is preferred for road building.

ABSORPTION CAPACITY

Related to the porosity of the rock types of which an aggregate is composed. Porous rocks are subject to disintegration when absorbed liquids freeze and thaw, thus decreasing the strength of the aggregate.

MAGNESIUM SULPHATE SOUNDNESS TEST

This test is designed to simulate the action of freezing and thawing on aggregate. Those aggregates which are susceptible will usually break down and give high losses in this test.

PETROGRAPHIC EXAMINATION

An aggregate quality test based on known field performance of various rock types. The test result is a Petrographic Number (P.N.). The higher the P.N. the lower the quality of aggregate. The percentage chert values given for the coarse aggregate in this appendix were taken from data for this test.

TABLE 6. SELECTED QUALITY REQUIREMENTS FOR MAJOR AGGREGATE PRODUCTS.

	TYPE OF TEST				
	COARSE AGGREGATE				FINE AGGREGATE
TYPE OF MATERIAL	Petrographic Number Maximum	Magnesium Sulphate Soundness - Max. % Loss	Absorption Maximum %	Los Angeles Abrasion Maximum % Loss	Magnesium Sulphate Soundness Maximum % Loss
Granular Base A	200	-	-	60	-
16 mm Crushed Type 'A'	160	-	-	35	-
16 mm Crushed Type 'B'	200	-	-	60	-
Granular Subbase B	250	-	-	-	-
Granular Subbase C	250	-	-	-	-
Granular Subbase D	-	-	-	-	-
Hot Mix - H. L. 1	100	5	1.0	15	16
Hot Mix - H. L. 2	-	-	-	-	20
Hot Mix - H. L. 3	135	12	1.75	35	16
Hot Mix - H. L. 4	160	12	2.0	35	20
Hot Mix - H. L. 8	160	15	2.0	35	20
Structural Concrete and Concrete Base	140	12	2.0	35	16
Pavement Concrete and Exposed Structure Deck	125	12	2.0	35	16

(M.T.C. Forms 1002, 1003 and 1010)

TABLE 7. RESULTS OF AGGREGATE QUALITY TESTS.

	COARSE AGGREGATE						FINE AGGREGATE
Sample No.	Petrographic Number Granular & 16 mm Crushed	Petrographic Number Hot Mix & Concrete	Chert Content	Magnesium Sulphate Soundness	Absorption	Los Angeles Abrasion	Magnesium Sulphate Soundness
Marathon Map Area							
Pit 11	100.2	106.7	1.2%	1%	.702%	16.80%	9.1%
Pit 13	106.0	138.8	5.7%	4%	1.004%	-	7.4%
Pit 18	109.8	115.7	0.8%	2%	.567%	29.62%	6.0%
Pit 27	106.0	129.2	0%	3%	.701%	-	0.9%
Pit 33	134.1	164.7	0.5%	5%	1.075%	-	10.0%
Pit 45	101.2	123.9	6.4%	2%	1.002%	-	3.0%
Pit 52	104.3	155.0	7.4%	-	1.974%	-	9.2%
Pit 66	101.6	149.5	8.4%	3%	1.688%	-	7.5%
HE-TH-1	101.1	133.5	3.2%	2%	.835%	-	10.2%
HE-TH-2	100.6	112.1	1.0%	2%	.635%	20.94%	12.1%
HE-TH-3	101.2	118.0	0.4%	3%	1.170%	-	7.1%
HE-TH-4	107.6	120.9	0.0%	1%	.802%	21.42%	8.9%
Manitouwadge Map Area							
Pit 81	107.3	125.6	4.8%	3%	1.103%	-	9.1%
Pit 84	115.5	175.4	11.2%	5%	2.019%	-	7.3%
Pit 91	105.9	169.8	14.4%	4%	-	-	9.6%
Pit 95	106.7	131.0	2.3%	3%	1.268%	27.76%	13.6%
White River Map Area							
Pit 112	104.0	113.5	1.0%	3%	.936%	-	8.2%
Pit 114	100.6	111.8	3.8%	1%	.768%	24.06%	6.9%
Pit 121	104.5	127.6	6.3%	1%	.936%	19.96%	5.4%
Pit 127	100.3	117.7	3.3%	1%	.767%	24.58%	8.0%
Pit 128	101.1	110.3	1.7%	1%	.735%	20.32%	5.5%
Pit 134	104.5	127.7	3.0%	4%	1.136%	-	12.2%
Pit 135	103.6	129.4	2.8%	2%	.835%	-	10.4%
Pit 142	100.0	103.0	0.7%	1%	.467%	-	3.1%
Pit 150	101.2	123.5	0.4%	2%	.501%	-	6.2%
HE-TH-10	108.8	157.4	8.8%	3%	1.402%	22.18%	10.9%
HE-TH-12	103.4	119.4	0.9%	2%	.768%	-	11.9%
HE-TH-13	102.4	108.2	0%	1%	.769%	-	8.4%
HE-TH-16	100.4	120.0	2.5%	2%	.969%	24.18%	7.7%
HE-SS-2	-	-	-	-	-	-	13.4%

NOTE: The quality refers strictly to a specific sample taken at the time of field investigation.
Due to the inherent variability of sand and gravel deposits care should be exercised in extrapolating such information to the rest of the deposit.

MAPS NOT

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OMISES